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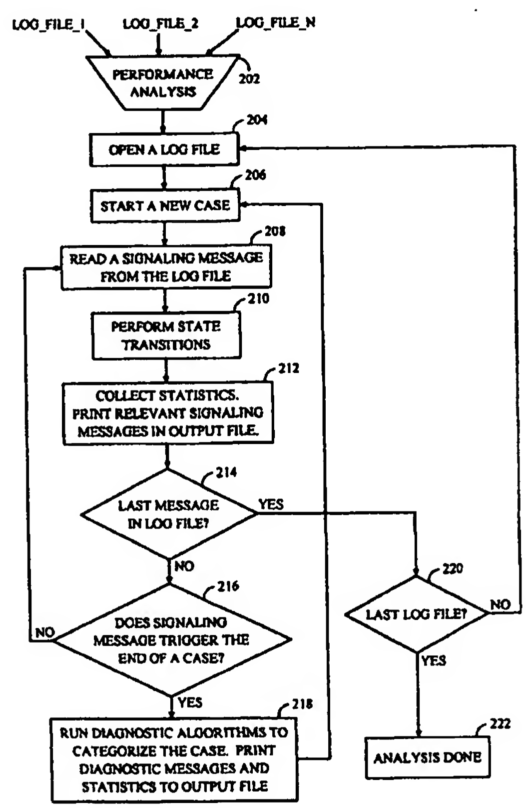
(57) Abstract

A performance analysis tool analyzes over-the-air messages transmitted between a test mobile station (MS) (110) and one or more base stations (BSs) (102, 104), which are recorded by a mobile diagnostic monitor (MDM) (112) in mobile log files. The tool views the log file containing the messages, and in response to certain trigger messages, transitions between different states. A series of state transitions comprises a "case", defined as a series of messages seen in the log file which culminates in a critical event. The tool can function both in a manner that assumes every message was perfectly logged (by the MDM) and in a manner including robust capacity, which accounts for messages which were transmitted but not recorded in the log files. The tool studies the behavior of the MS (110) and BSs (102, 104) for either normal or abnormal state transitions. For normal state transitions, the tool emulates normal functions of the MS (110). For abnormal state transitions, the tool diagnoses problems by integrating log file information, communication system standards, and systems engineering knowledge. The tool provides several outputs, including detailed studies for each case.



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SYSTEM AND METHOD FOR ANALYZING MOBILE LOG FILES

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates generally to the field of telecommunications, and more specifically to a system and method for enhancing analysis of mobile log files used by field and systems engineers to determine the network performance of a wireless communication system.

II. Description of the Related Art

In this day of sophisticated wireless communication systems (e.g., cellular communications systems), it is vital to test the establishment and completion of communications between a mobile station and base stations offered by the telecommunications carrier. This is particularly true for more sophisticated cellular systems, such as Code Division Multiple Access (CDMA) systems employed by Qualcomm Incorporated, the assignee of this invention. Testing occurs both during the initial establishment of a cellular system and during subsequent optimization of the cellular system.

Field engineers can be sent to the field equipped with special test mobile stations. These test mobile stations are for the most part the same as regular mobile stations, except that they are connected to a computer, such as a laptop computer. The connection with the laptop enables all over-the-air messages transmitted between the test mobile station and the base stations to be recorded. The test mobile stations transmit these signals to the laptop at a very high rate. The laptop queues the messages and quickly stores them on a hard drive in a log file, for example in an ASCII format.

Unfortunately, these ASCII log files are vast in size, making it extremely difficult for a systems engineer to decipher useful information from them. For example, just five minutes worth of logged messages between a base station and the test mobile station amounts to 1.6 megabytes of memory or equivalently around 650 pages of information as viewed by a text editor. On the other hand, certain enhanced logging mechanisms that log information at high data rates could result in log files of sizes up to 5 megabytes or equivalently up to 2000 pages of data for a five minute run. In a typical drive test, where the field engineer is driving in the field with a test mobile station, data is collected for approximately an hour, resulting in log

file sizes of 10-20 megabytes. In the mobile log file, each message that the mobile station sends or receives is typically displayed in multiple lines. For example, a simple message like the System Parameters message sent by a base station in a CDMA cellular system is displayed in 15-20 lines. In other automated logging tests, one could log files over night or during a whole day to produce log files as big as 300 Meg.

Considering the enormous sizes of the mobile log files, manual viewing of a log file by a systems engineer trying to determine cellular network performance is a difficult and often Herculean task. The systems engineer desiring to analyze network performance must view thousands of messages, each with multiple lines of information. In the traditional method of analysis of mobile log files, an experienced systems engineer develops the skills to visually browse through these huge files, continuously correlating the data viewed with a specific hypothesis the systems engineer has in mind about a call event. If the systems engineer finds enough evidence of a problem, the systems engineer will denote the time stamps where there may be problems and plausible reasons as to why these problems occurred.

The inherent shortcomings of this approach are obvious. It is almost impossible to catch all the problems in a large mobile log file manually. The systems engineer must spend a great deal of time developing the skills to analyze log files before the systems engineer can produce reliable results, so that a novice systems engineer is at a definite disadvantage. Even for an experienced systems engineer, the enormous amount of information makes the process prone to error. Accordingly, the size of the mobile log files collected in a test drive is limited by the capacity and the time constraints of the systems engineers who perform the analysis.

Another problem arises from the difference in rate between how quickly the test mobile station transmits signals to the laptop and how quickly the laptop is able to store the signals. Unfortunately, the speed at which the test mobile station transmits signals to the laptop is very high, typically much faster than the rate at which even high performance laptop computers can receive or store the information. In these cases, messages can be missing from the mobile log file, many of which are important for deciding the causes of critical events. A systems engineer must be able to decipher the mobile log file despite such omissions, which is a tedious and often daunting task.

SUMMARY OF THE INVENTION

The present invention is a performance analysis tool that analyzes the over-the-air messages transmitted between a test mobile station and one or more base stations. The analysis tool views a mobile log file, generated by a specialized laptop computer (called a Mobile Diagnostic Monitor), containing these messages. In response to certain messages, denoted "trigger messages," the analysis tool transitions between different states. A series of state transitions comprise a "case." A case is defined as a series of messages seen in the log file which culminates in a critical event, including call-related successes and failures and other non-call specific failure mechanisms (e.g., those defined in the standard IS-95-A for cellular systems and those defined in the standard JST-008 for PCS systems). Hence, a case is the series of messages seen after the end of a previous case until the culmination of a critical event.

The analysis tool of the present invention can operate in either of two different embodiments. The first embodiment assumes perfect logging. Here, it is assumed that all of the over-the-air messages between the mobile station and the base stations were recorded in the log file by a mobile diagnostic monitor. The second embodiment is a robust mode. In the robust mode embodiment, the analysis tool accounts for the fact that often the mobile station transmits messages (notably trigger messages) to the mobile diagnostic monitor faster than the monitor can save these messages, causing a situation where the log file is missing messages even though these messages were actually transmitted. The perfect logging mode embodiment and the robust mode embodiment differ in that the robust mode permits additional state transitions, based on the detection of trigger messages in pre-determined states, that are not permitted in the perfect logging mode embodiment.

In either the perfect logging or the robust mode embodiments, state transitions can be normal or abnormal. A normal state transition indicates that the detected trigger message is an appropriate message that either the mobile station is expecting to receive from the base station, or the base station is expecting to receive from the mobile station. When the trigger

message is received, the analysis tool emulates the normal functions of the mobile station, in order to recreate the states of the mobile station. This can include maintaining timers and counters. Timers are used to count time periods during which pre-determined events must occur, whereas counters count the number of times pre-determined events must occur. When timers "time out" or counters "count out," the mobile station indicates a failure condition. The analysis tool also maintains these failure conditions upon viewing the occurrence of the trigger messages and their time stamps in the log file.

An abnormal transition occurs when detection of a trigger message is not expected in a state. Abnormal transitions are handled by ignoring them if they are considered nonconsequential to maintaining valid communications, or determining their causes if they are considered consequential. Notably, if a trigger message invokes a state transition between any initial state (including the first two states) and the first two states, the state transition is always considered consequential and is diagnosed. During diagnosis, the analysis tool views a variety of information from the log file to diagnose the problem, including both trigger and non-trigger messages, time stamps, time outs, count outs, pilots, signal strengths, received power and multipath conditions. Diagnoses involve an integration of information available from the log files, the wireless communication standards of the system, and knowledge available only to an experienced systems engineer. The diagnoses result in outputs indicating the failures found.

For each studied case, the analysis tool provides an output of its analysis. One type of output is a case study, where the trigger messages (including relevant information about each of them) and diagnosis outputs are provided. Other important outputs include statistics that may reveal problems associated with detections of neighbor lists, handoff distributions, handoff setup time, call setup time, pilot acquisition time, multipath, jumping to hyperspace, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described with reference to the accompanying figures, wherein:

FIG. 1 is illustrates the inventive mobile station environment;

FIG. 2 is a flow chart illustrating the functions of the inventive performance analysis tool;

FIG. 3 is a high level state diagram illustrating the substates of the first inventive state;

FIG. 4 is a high level state diagram illustrating the inventive state transitions;

FIG. 5 is a low level state diagram illustrating state transitions under perfect logging conditions;

FIG. 6 is a low level state diagram illustrating robust state transitions;

FIG. 7 is a low level state diagram illustrating a combination of figures 5 and 6 to provide a robust logging state diagram;

FIG. 8 is a flow chart illustrating diagnose state transitions for a transition from state 1 back to state 1;

FIG. 9 is a flow chart illustrating diagnose state transitions for a transition from state 2 to state 1;

FIG. 10 is a flow chart illustrating diagnose state transitions for a transition from state 2 to state 2;

FIG. 11 is a flow chart illustrating diagnose state transitions for a transition from state 3 to state 1;

FIG. 12 is a flow chart illustrating diagnose state transitions for a transition from state 3 to state 2;

FIG. 13 is a flow chart illustrating diagnose state transitions for a transition from state 4 to state 2;

FIG. 14 is a flow chart illustrating diagnose state transitions for a transition from state 4 to state 1;

FIG. 15 is a flow chart illustrating diagnose state transitions for a transition from state 5 to state 1, as well as a transition from state 6 to state 1;

FIG. 16 is a flow chart illustrating diagnose state transitions for a transition from state 7 to state 1;

FIGs. 17A and 17B illustrate the diagnostic messages that the inventive analysis tool can output for cases;

FIG. 18 illustrates the format used by the inventive analysis tool to output trigger messages for case studies;

FIG. 19 illustrates sample case studies performed for two exemplary log files;

FIGs. 20A-20D illustrate outputs of additional observations performed;

FIG. 21 illustrates an implementation of the invention.

In the figures, like reference numbers generally indicate identical, functionally similar, and/or structurally similar elements. The figure in which an element first appears is indicated by the leftmost digit(s) in the reference number.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

1. The mobile station environment

FIG. 1 illustrates a mobile station environment 100 used to explain the invention. In a preferred embodiment, mobile station environment 100 is a Code Division Multiple Access (CDMA) cellular system. Mobile station environment 100 includes base stations (BSs) 102, 104, cell coverage areas 106, 108 and mobile station (MS) 110. MS 110 is a test mobile station used by a field test engineer to determine whether communications is properly established and conducted in mobile station environment 100.

Accordingly, MS 110 is connected to a Mobile Diagnostic Monitor (MDM) 112. MDM 112 logs over-the-air messages that are exchanged between MS 110 and BSs 102, 104 in an MS log file (hereinafter "log file"). In a preferred embodiment, MDM 112 is laptop-based tool developed by QUALCOMM Incorporated, although those skilled in the relevant arts will recognize that any comparable computer can perform a similar function.

If mobile station environment 100 is a standard CDMA cellular system, the over-the-air messages correspond to the IS-95-A standard (TIA/EIA Interim Standard, "Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System", TIA/EIA/IS-95-A, May 1995). IS-95-A is the digital CDMA standard for cellular systems in the United States and abroad.

If the mobile station environment 100 is a CDMA Personal Communication System (PCS), the over-the-air messages correspond to the J-STD-008 standard. Both this standard and the IS-95-A standard are well known to those skilled in the relevant arts.

The log file contains a variety of information which can be used to characterize the performance of MS 110, the BSs 102, 104, and the system as a

whole. The log file is very useful to field test engineers not only during the deployment stage, when mobile station environment 100 is first deployed, but also during the subsequent optimization stage of the CDMA system, to optimize the performance of mobile station environment 100. The log file can be a human-readable file, derived from a binary machine-readable file where the messages are initially stored, or instead can be a binary machine-readable file, itself. This will be recognized by those skilled in the art.

Although the present invention is described in terms of the example embodiment described above, the description in such terms is for convenience only. It is not intended that the invention be limited to this example embodiment. For example, mobile station environment 100 is described as a CDMA cellular or a CDMA PCS system. However, the mobile station environment represents any wireless communication system. The wireless communication system can be a digital or an analog system. Some examples include an AMPS system, a TDMA system, a GSM system, any future implementations of CDMA systems, or any other PCS or cellular systems (e.g., other than CDMA). It is also possible to use the present invention with wireless communications systems that do not use mobile stations, such as a system having wireless local loop (WLL) phones. In fact, after reading the following description, it will become apparent to persons skilled in the relevant art(s) how to implement the present invention in alternative embodiments.

2. The inventive performance analysis tool

The present invention is a performance analysis tool (hereinafter "analysis tool") used to study mobile station environment 100 by analyzing the over-the-air messages stored in one or more log files. As will be recognized by those skilled in the art, the analysis tool can be any combination of hardware and software, including a hardware state machine. In one embodiment, the analysis tool comprises one or more "C" language programs running on a DOS operating system on a laptop personal computer, the same laptop that is running MDM 112. However, those skilled in the art will recognize that the present invention can be implemented using any known language running on any known operating system using any known type of type of computer.

FIG. 2 is a high-level flowchart that illustrates the functions of the analysis tool. In step 202, one or more log files (e.g., Log_File_1, Log_File_2) are input to the analysis tool. These log files are preferably processed

sequentially. In a preferred embodiment, the log files are in an ASCII format.

In step 204, the first log file, i.e., Log_File_1, is opened. In step 206, the analysis tool starts a new "case." A case is defined as a series of messages seen in the log file which culminates in a critical event, including call-related successes and failures and other non-call specific failure mechanisms (e.g., those defined in the standard IS-95-A for cellular systems and those defined in the standard JST-008 for PCS systems). Hence, a case is the series of over-the-air messages seen after the end of a previous case until the culmination of a critical event, which have been exchanged between MS 110 and a base station, e.g., BS 102. For example, each case can denote a series of transitions between when MS 110 is powered-up, or enters a service area system, and when communications between MS 110 and the base station is effectively halted (either through a normal call termination or through a failure).

In step 208, the over-the-air signaling messages are read, beginning with the first message of the first case of the first log file. In step 210, for each over- the-air message, the analysis tool performs state transitions. These state transitions are explained in detail below with reference to FIGs. 3-7. During these state transitions, the analysis tool collects relevant information and prints relevant over-the-air messages in output files as shown in step 212. These printouts are explained in detail below with reference to FIGs. 17A-20D.

Steps 214 and 220 are recursive decision steps to ensure that the processing is performed for each over-the-air message in each log file. From step 220, analysis is ended (in step 222) if the last log file is reached, or analysis continues (in step 204) if there are more unprocessed log files. Similarly, step 216 is a recursive decision step to ensure that the processing is performed for each new case.

In step 218, a series of diagnostic algorithms are run to categorize each case, into one of several scenarios. These diagnostics are run when a transition to a low state occurs or, if no such low-state transition occurs, when the case ends. The diagnostic algorithms are explained in detail with respect to FIGs. 8-16. The diagnostic messages and relevant statistics (including message time stamps) are printed to output files. These output files are illustrated in FIGs. 17A-20D.

3. CDMA time limits and constants

The present invention makes wide use of CDMA time limits and constraints. Tables 1 and 2 contain such constraints as defined by the IS-95-A standard (for cellular systems). As will be recognized by those skilled in the art, the relevant time limits and constraints will depend upon the type of wireless communication system used, and hence the listed time limits and constraints in no way limit the present invention.

Table 1 provides time limits, denoted as T_{nm} or T_{nb} (where n is an integer), with corresponding descriptions and values. In CDMA, timers are set to these time limit values to indicate the occurrence of events. For example, T_{1m} is the maximum time that the mobile station waits for an acknowledgment, and is set to 0.4 seconds. Accordingly, a timer set to T_{1m} will time out after 0.4 seconds. The subscript "m" indicates that a time limit or constraint is for a mobile station, whereas the subscript "b" indicates a time limit or constraint is for a base station.

Table 1. Time Limits

Time Limit	Description	Value
T_{1m}	Maximum time the mobile station waits for an acknowledgment	0.4 s
T_{2m}	Maximum time allowed for the mobile station to send an acknowledgment	0.2 s
T_{3m}	Period in which two messages received by the mobile station on the Forward Traffic Channel, not requiring an acknowledgment, and carrying the same sequence numbers, are considered duplicates	0.32 s
T_{4m}	Period in which two messages received by the mobile station on the same Paging Channel and carrying the same sequence numbers are considered duplicates	2.2 s
T_{5m}	Limit of the Forward Traffic Channel fade timer	5 s
T_{20m}	Maximum time to remain in the *Pilot Channel Acquisition Substate* of the *Mobile Station Initialization State*	15 s
T_{21m}	Maximum time to receive a valid Sync Channel message	1 s
T_{30m}	Maximum time to receive a valid Paging Channel message	3 s
T_{31m}	Maximum time for which configuration parameters are considered valid	600 s
T_{32m}	Maximum time to enter the *Update Overhead Information Substate* of the *System Access State* to respond to an *SSD Update message, BS Challenge Confirmation Order,* and *Authentication Challenge message*	5 s

T_{33m}	Maximum time to enter the *Update Overhead Information Substate* of the *System Access State* to respond to messages received while in the *Mobile Station Idle State* (except authentication messages)	0.3 s
T_{34m}	Maximum time to enter the *Update Overhead Information Substate* or the *Mobile Station Idle State* after receiving a *Channel Assignment message* with $ASSIGN\_MODE_r$ equal to '001'	3 s
T_{40m}	Maximum time to receive a valid Paging Channel message before aborting an access attempt	1 s
T_{41m}	Maximum time to obtain updated overhead messages arriving on the Paging Channel	4 s
T_{42m}	Maximum time to receive a delayed layer 3 response following the receipt of an acknowledgment for an access probe	12 s
T_{50m}	Maximum time to obtain N_{5m} consecutive good Forward Traffic Channel frames when in the *Traffic Channel Initialization Substate* of the *Mobile Station Control on the Traffic Channel State*	0.2 s
T_{51m}	Maximum time for the mobile station to receive a *Base Station Acknowledgment Order* when in the *Traffic Channel Initialization Substate* of the *Mobile Station Control on the Traffic Channel State*	2 s
T_{52m}	Maximum time to receive a message in the *Waiting for Order Substate* of the *Mobile Station Control on the Traffic Channel State* that transits the mobile station to a different substate or state	5 s
T_{53m}	Maximum time to receive a message in the *Waiting for Mobile Station Answer Substate* of the *Mobile Station Control on the Traffic Channel State* that transits the mobile station to a different substate or state	65 s
T_{54m}	Maximum time for the mobile station to send an *Origination Continuation Message* upon entering the *Conversation Substate* of the *Mobile Station Control on the Traffic Channel State*	0.2 s
T_{55m}	Maximum time to receive a message in the *Release Substate* of the *Mobile Station Control on the Traffic Channel State* that transits the mobile station to a different substate or state	2 s
T_{56m}	Default maximum time to respond to a received message or order on the Forward Traffic Channel	0.2 s
T_{57m}	Limit of the power-up registration timer	20 s
T_{58m}	Maximum time for the mobile station to respond to a service option request	5 s
T_{59m}	Reserved	0.06 s

T_{60m}	Maximum time to execute a hard handoff involving a new frequency assignment using the same base station	0.08 s
T_{61m}	Maximum time to execute a hard handoff involving a new frequency assignment using a different base station	0.02 s
T_{62m}	Maximum time to execute a hard handoff involving the same frequency assignment	0.02 s
T_{63m}	Maximum time to execute a CDMA to Analog handoff	0.1 s
T_{64m}	Maximum time to wait for a *Base Station Challenge Confirmation Order*	10 s
T_{1b}	Maximum period between subsequent transmissions of an overhead message on the Paging Channel by the base station	1.28 s
T_{2b}	Maximum time for the base station to send a *Release Order* after receiving a *Release Order*	0.8 s
T_{3b}	Minimum time the base station continues to transmit on a code channel after sending or receiving a *Release Order*	0.3 s
T_{4b}	Maximum time for the base station to respond to a service option request	5 s

Table 2 contains other constraints, denoted as N_{nm} (where n is an integer), with corresponding descriptions and values. These other constraints are primarily counter-based. For example, N_{1m} is the maximum number of times that a mobile station transmits a message requiring an acknowledgment on the reverse traffic channel. N_{1m} has a value of 3. Accordingly, a counter set to N_{1m} "counts out" after three mobile station messages requiring such an acknowledgment.

Table 2. Other Constants

Constant	Description	Value
N_{1m}	Maximum number of times that a mobile station transmits a message requiring an acknowledgment on the Reverse Traffic Channel	3
N_{2m}	Number of received consecutive bad Forward Traffic Channel frames before a mobile station must disable its transmitter	12
N_{3m}	Number of received consecutive good Forward Traffic Channel frames before a mobile station is allowed to re-enable its transmitter after disabling its transmitter	2
N_{4m}	Reserved	

N_{5m}	Number of received consecutive good Forward Traffic Channel frames before a mobile station is allowed to enable its transmitter after entering the *Traffic Channel Initialization Substate* of the *Mobile Station Control on the Traffic Channel State*	2
N_{6m}	Supported Traffic Channel Active Set size	6
N_{7m}	Supported Traffic Channel Candidate Set size	5
N_{8m}	Minimum supported Neighbor Set size	20
N_{9m}	Minimum supported zone list size	7
N_{10m}	SID/NID list size	4
N_{11m}	Number of received consecutive good Forward Traffic Channel frames before a mobile station re-enables its transmitter after disabling its transmitter during a CDMA to CDMA Hard Handoff	1

4. Communication links between BS 102 and MS 110

FIG. 1 illustrates two links between BS 102 and MS 110. These links are a forward link 114 and a reverse link 116.

a. Forward link

Forward link 114 refers to the communication directed from BS 102 to MS 110. Communication over forward link 114 is over a pilot channel, a sync channel, a paging channel, and a forward traffic channel.

i. Pilot channel

The pilot channel is transmitted at all times by BS 102 on each active forward CDMA channel. The pilot channel is an unmodulated spread spectrum pseudo random (PN) signal that is used for synchronization by MS 110 operating within the coverage area 106 of BS 102. The base stations are distinguished by a PN offset value chosen from a set of integers in the range of 0-512, with increments determined by the system setup. The PN offset is used to delay a short code PN sequence to produce PN sequences that have good correlation properties and are used to uniquely identify the base stations.

ii. Sync channel

The sync channel (hereinafter "SCH") is a channel used to provide time and frame synchronization to MS 110. Only one message, the SCH message, is sent on the SCH.

iii. Paging channel

The paging channel (hereinafter "PCH") is a channel used to send control information to MS 110 if it is an unassigned mobile station area. MS 110 is an unassigned mobile station area if it has not yet been assigned to a traffic channel.

iv. Forward traffic channel

The forward traffic channel (hereinafter "forward TCH") is used for transmission of user and signaling information to MS 110 during a call. The maximum number of forward TCHs that can be simultaneously supported by a given forward CDMA channel is 63 minus the number of PCHs and SCHs operating on the same forward CDMA channel.

b. Reverse link

Reverse link 116 is the communication directed from MS 110 to BS 102. Communication over the reverse link is over an access channels and a reverse traffic channel.

i. Access channel

The access channel (hereinafter "ACH") is used by MS 110 to initiate communication with BS 102 and to respond to PCH messages. An ACH transmission is a spread-spectrum signal that is coded, interleaved, and modulated. The ACH uses a random-access protocol. ACH signals are uniquely identified by their long codes.

ii. Reverse traffic channel

The reverse traffic channel (hereinafter "reverse TCH") is similar to the forward TCH. The reverse TCH is used for transmission of user and signaling information to BS 102 during a call.

5. High level description of state transitions

The analysis tool of the present invention uses state analysis to analyze MS environment 100. FIGs. 3 and 4 are high level state diagrams used to illustrate the state analysis.

As noted, the state transitions are triggered by the viewing of recorded over-the-air messages in the log files. Specifically, the state transitions are performed for each individual case for each log file. When the analysis tool is in a given state, certain messages viewed in the log file will cause the tool to transition to different transition states. After each state transition, the analysis tool collects important information regarding the

states of MS 110, BS 102 (assuming MS 110 is in cell coverage area 106 of BS 102), and mobile station environment 100 in general. It is important to note that these states of the inventive analysis tool correspond to modes of MS 110, itself. Therefore, the analysis tool states are in actuality analysis states corresponding to the mode of MS 110.

Referring to FIG. 4, column A shows the trigger messages that invoke state transitions for the analysis tool. These trigger messages are transmitted between MS 110 and BS 102. For convenience, arrows are used to indicate the direction of these messages. Column B shows the transition states of the analysis tool. Column C shows certain counters and timers used to detect failures in each of the transition states. As noted, the counters and timers respectively "count out" or "time out" when counted and timed events are not satisfied within pre-defined constraints.

a. State 0

FIG. 4 begins with the analysis tool in state 0. This is the step where MS 110 is initially powered up, or every time the mobile station ends a call in or is brought into cell coverage area 106 of BS 102.

b. State 1

Upon the initial power-up or the transport into cell coverage area 106, state 1 is entered. FIG. 3 is a detailed view of state 1. State 1, itself, comprises four substates: system determination substate 302, pilot channel acquisition substate 304, SCH acquisition (or SCH) substate 306 and idle substate 308.

FIG. 3 begins with the system determination substate 302. During system determination substate 302, MS 110 selects which cellular system (e.g., CDMA system of BS 102).

After system determination is performed, the pilot acquisition substate 304 is entered. In pilot acquisition substate 304, MS 110 attempts to acquire the strongest pilot signal it is receiving from neighboring base stations. If MS 110 is in cell coverage area 106 of BS 102, MS 110 sequentially runs through a list of prestored PNs (pseudorandom pilot signals), to find a match with the PN transmitted from BS 102.

If the pilot channel is acquired within T_{20m} (see Table 1), then the SCH acquisition substate 306 is entered, where the SCH is opened for communications. In the SCH acquisition substate 306, MS 110 awaits an SCH messages on the SCH to obtain configuration and timing information

for the CDMA system. This information is required for a transition to idle substate 308, where the PCH is acquired. However, if a valid SCH message is not received in T_{21m}, indicating an error condition, then a transition back to system determination substate 302 occurs.

As noted, the SCH message causes a transition from SCH substate 306 to idle substate 308, both of which are in state 1 for the analysis tool. Therefore, the SCH message is a trigger between substates 306 and 308 of MS 110 within state 1, and not a trigger between different states of the analysis tool.

FIG. 4 shows state 1 of the analysis tool as a combination of the four substates 302-308 of MS 110. When SCH message 408 (for the case being analyzed) is read from the log file, the analysis tool transitions from the SCH substate to the idle substate within state 1.

As noted, in the idle substate of state 1, MS 110 has acquired the PCH and receives communications from BS 102 on the PCH. Upon entering the idle substate of state 1, the T_{30m} timer is maintained. If a valid PCH message is not received within T_{30m}, then the analysis tool returns to the system determination substate. After the transition to the idle substate of state 1, i.e., the PCH is opened for communications, then MS 110 can transmit communications on the reverse link to BS 102 over an opened ACH.

c. **State 2**

There are three messages transmitted by MS 110 over the ACH that will cause the analysis tool to transition from the idle substate of state 1 to access state 2. These three messages are Origination message, Page Response message, and Registration message (item 410). All three of these messages are sent from MS 110 to BS 102 over the ACH. It should be noted that these messages, as all other trigger messages discussed herein, are read from the log file. The messages are typically transmitted using access probes. As recognized by those skilled in the art, access probes are messages that begin as weak signals and become greater in strength, until they are heard by the receiver, which is in this case BS 102. Access probes are used to conserve the energy of MS 110 and to reduce interference in the system.

The Origination message is a message indicating MS 110 desires to originate a call. The Page Response message is a message by MS 110 indicating its response to an incoming call (i.e., a call terminating at MS 110, which is also known as a terminating call). The Registration message is a

message by MS 110 indicating that it desires to register in the current CDMA system.

In access state 2, MS 110 awaits a Base Station Acknowledgment (Ack) Order message, on the PCH, from BS 102. The Base Station Ack Order message on the PCH is a confirmation message indicating that BS 102 has heard the Origination message access probes, Page Response message access probes, or Registration message access probes sent by MS 110.

After the first message probe is sent in the idle substate of state 1, i.e., as soon as access state 2 is entered, the counter max_probes begins maintaining a count of the number of access probes transmitted. If the number of access probes transmitted exceeds max_probes (which is defined by the IS-95-A standard), then a failure condition is indicated.

The T_{40m} timer is also maintained in access state 2, timing out if a valid PCH message is not received within T_{40m} seconds. The T_{40m} timeout is always used to determine whether the PCH is good, meaning that there has not been any loss (or fade) in signal. A T_{40m} timeout indicates a failure condition.

d. State 3

When a valid Base Station Ack Order message 412 acknowledging the access probes is received by MS 110 over the PCH, then access state 3 (a second access state) is entered, i.e., when the access probe is for call origination or call termination and indicates that MS 110 is waiting for a Channel Assignment message.

If MS 110 is in the registration procedure (i.e., it had sent out a Registration message), then the analysis tool need not proceed any further to higher states. MS 110 is already registered at this point.

However, for call origination and call termination (i.e., MS 110 had transmitted an Origination message or a Page Response message), then the analysis tool can transition to the higher states. The T_{40m} timer is also maintained in access state 3, timing out if a valid PCH message is not received within T_{40m} seconds. The T_{40m} timeout is always used to determine whether the PCH is good. A T_{40m} timeout indicates a failure condition.

In access state 3, MS 110 awaits a Channel Assignment message 414 on the PCH from BS 102. The Channel Assignment message 414 is a message containing the frequency and code channel on which a user using MS 110 can communicate. The frequency and code channels identify and open the forward TCH from BS 102 to MS 110. Upon entering access state 3, the T_{42m} timer is maintained. If the Channel Assignment message 414 is not received

within T_{42m} seconds from the time the Base Station Ack Order message 412 is received, then a failure condition is indicted.

e. **State 4**

Once BS 102 sends the Channel Assignment message 414 and it is viewed in the log file, a transition to state 4 occurs. State 4 is the jump to the TCH state. Here, MS 110 determines whether the forward TCH is set up properly, and once this determination is made, MS 110 sets up the reverse TCH. This is performed by way of receiving a forward link preamble, sending a reverse link preamble, and maintaining timers. MS 110 maintains two timers in jump to TCH state 4. The first timer is T_{50m}. This is the maximum time given for N_{5m} consecutive valid null data frames to be received on the forward TCH from BS 102. These forward TCH null data frames comprise the forward link preamble. If the T_{50m} timer expires, a failure condition is indicated. However, if this test is passed, MS 110 then sets up the reverse TCH by sending out the reverse link preamble on the reverse TCH.

MS 110 also maintains the T_{51m} timer. This is the maximum time permitted for a Base Station Ack Order message 416 from BS 102 over the forward TCH, acknowledging that the null data frames (comprising the reverse link preamble) transmitted from MS 110 have been received by BS 102. Time out of timer T_{51m} indicates a failure condition.

f. **States 5, 6 and 7**

Once BS 102 sends the Base Station Ack Order message 416 on the TCH, a transition to state 5 occurs, which is called the first Base Station Ack Order message on the TCH state. Transition to state 5 indicates that both the forward and reverse TCHs have been successfully initialized, for full duplex communications.

Any TCH messages received after state 5 forces a transition to state 6, which is the TCH messaging state. During this state, full duplex communications over the forward and reverse TCHs occurs between MS 110 and BS 102. State 6 transitions to state 7 when either party (either the MS 110 or the BS 102) transmits to the other a Release Order message 420. State 7, referred to as the call ends state, is the last state.

The TCHs (both forward and reverse links) are monitored via the T_{5m}, T_{52m}, T_{55m} timers and the N_{1m} counter. If any of these timers "time out" or these counters "count out," then a failure conditions is indicated. Expiration of the T_{5m} timer indicates that there is a fade in the signal and

the forward TCH is effectively lost. For a call termination, expiration of the T_{52m} timer indicates that MS 110 did not receive an Alert With Information message. Expiration of the T_{55m} timer indicates that BS 102 is not responding when MS 110 tries to release a call. Finally, N_{1m} counts out if MS 110 keeps retransmitting reverse TCH messages N_{1m} times without any response from BS 102.

6. Detailed description of state transitions

FIGs. 5-7 illustrate the state diagrams for the present invention at a lower level. The level A diagram of FIG. 5, the level B diagram of FIG. 6, and the level C diagram of FIG. 7 provide a more detailed view of the inventive state transitions, particularly during abnormal call conditions.

a. State Transitions assuming perfect logging

The level A state diagram of FIG. 5 illustrates basic state transitions between states 1-7 under the assumption that logging is perfect. Perfect logging means that every over-the-air message transmitted between MS 110 and BS 102 is reproduced in its entirety in the log file. As noted, the analysis tool transitions between the states depending upon whether certain trigger messages, transmitted between MS 110 and BS 102, are detected in the log file.

Table 3 illustrates abbreviations for these trigger messages. These abbreviated messages are used in FIGs. 5-7. In Table 3, the letters **a, e** represents detection of an Origination message, a Page Response message, or a Registration message (transmitted by way of access probes) in the log file. The letter **b** represents the detection of an SCH message. The letter **c** represents detection of a Base Station Ack Order message on the PCH. The letter **d** represents detection of a Channel Assignment message in the log file. The letter **f** represents detection of a first Base Station Ack Order message on the TCH. The letter **g** represents detection of TCH messages, other than the first Base Station Ack Order message, on the TCH. Finally, the letter **h** represents detection of a Release Order message, either from MS 110 to BS 102 or from BS 102 to MS 110.

Table 3

State Transition	Message Logged
a, e	Orientation message/Page Response message/Registration message access probes for a new access attempt

b	Sync Channel message
c	Base Station Ack Order message (on PCH)
d	Channel Assignment message
f	First Base Station Ack Order message (on TCH)
g	Traffic Channel Messages, other than the first Base Station Ack Order message (on TCH)
h	Release Order messages from MS or BS

Table 4 explains in detail the state transitions of the level A state diagram of FIG. 5. The state transitions of FIG. 5 are those state transitions for cases where logging is perfect. Table 4 also includes the state transitions of the level B state diagram of FIG. 6 and the level C state diagram of FIG. 7.

As described in table 4, certain state transitions that were not noted in section 5 are considered either acceptable state transitions or errors too minor to warrant a problem diagnosis. These state transitions include d_{44}, f_{55}, f_{65}, g_{56}, g_{66}, h_{57}, h_{67}, h_{77}. For example, if a TCH message other than the first Base Station Ack Order message is received from BS 102 while the analysis tool is in state 6, this will cause a state transition back to state 6. This state transition, called the g_{66} state transition, is considered a normal event.

Table 4

State Transition	Message Logged	Remarks
a_{12}	Origination message/ Page Response message/ Registration message access probes for a new access attempt	Start counting the access probes, maintain T_{40m} timer, look for Base Station Acknowledgment Order message on the paging channel.

b_{11} Diagnose	Sync Channel message	A Sync Channel message in State 1 indicates that the paging channel is lost due to (1) loss of paging channel in the idle substate (T_{30m}), or (2) loss of acquisition after sleep (slotted mode), or (3) new system exit, or (4) a timing change substate problem, or (5) the phone could have been redirected to the analog system. Refer to FIG. 8.
b_{21} Diagnose	Sync Channel message	A Sync Channel message seen in State 2 indicates that the mobile station aborted the access attempt for one of the following reasons: (1) the mobile station sent the maximum number of access probes, or (2) if the current access attempt is a registration procedure, the base station could have sent a Registration Accepted message or a Rejected Order message, or (3) for call origination or call termination procedures, the base station could have sent a Release Order message or a Reorder Order message, or (4) the mobile could have lost the paging channel in the access state (T_{40m}) followed by a loss of the paging channel in the idle substate (T_{30m}), or (5) the user could have aborted the call attempt. Disable T_{40m}, enable maintenance of T_{30m} timer. Refer to FIG. 9.

$^{a}22$ Diagnose	Origination message/ Page Response message/ Registration message access probes	If these access channel messages are for the current access attempt, count the access probes, maintain T_{40m} timer, and look for the Base Station Acknowledgment Order message on the paging channel. However, if the access probes belong to a new access attempt, the mobile station could have aborted the access attempt for one of the following reasons: (1) if the current access attempt is a registration procedure, the base station could have sent a Registration Accepted message or a Rejected Order message, or (2) for call origination or call termination procedures, the base station could have sent a Release Order message or a Reorder Order message, or (3) the mobile station could have lost the paging channel in the access state (T_{40m}). Refer to the FIG. 10.
$^{c}23$, $^{c}33$	Base Station Acknowledgment Order message on the paging channel	Maintain the timers T_{40m} and T_{42m}, look for the Channel Assignment message for call originations or call terminations.

b_{31} Diagnose	Sync Channel message	If the current access attempt is for registration, then a Sync Channel message (SCM) might indicate that the mobile could have lost the paging channel in the access state (T_{40m}) and/or idle substate (T_{30m}). For call originations or call terminations, if the SCM is received T_{42m} sec after entering State 3, the mobile could have gone into the idle substate and lost the paging channel in the idle substate (T_{30m}). Disable T_{40m}, T_{42m} and enable maintenance of T_{30m} timer. Refer to FIG. 11.
e_{32} Diagnose	Origination message/ Page Response message/ Registration message access probes for a new access attempt	If the current access attempt is a registration, these messages indicate the beginning of a new access attempt. However, for call originations or call terminations, these messages indicate that the mobile station aborted the access attempt because (1) it lost the paging channel in access state (T_{40m}), or (2) it did not receive a Channel Assignment message within T_{42m} after entering this state, or (3) the base station sent other messages like a Release Order message or a Reorder Order message on the paging channel. Disable T_{42m} and count the access probes. Refer to FIG. 12.
d_{34}	Channel Assignment message	Disable T_{40m} and T_{42m} and start maintaining T_{50m} and T_{51m} timers and wait for the Base Station Acknowledgment Order message on the traffic channel

d_{44}	Channel Assignment message	Theoretically, the phone should jump onto the traffic channel on the first occurrence of the Channel Assignment message. Possibly, check why the log file shows repetitions of the Channel Assignment message.
e_{42} Diagnose	Origination message/ Page Response message/ Registration message access probes for a new access attempt	These messages received while in State 4 indicate that the mobile station ignored the Channel Assignment message. The reasons could include: (1) the mobile station could have rejected the Channel Assignment message via an Access Channel Order message because it is no longer in the access state, or (2) a loss of paging channel in the access state (T_{40m}) occurred, or (3) because the Channel Assignment message is received T_{42m} seconds after the Base Station Acknowledgment Order message, when the mobile station transitions to the idle substate. Disable T_{50}, T_{51m} timers, start maintaining T_{40m} timer, and count the number of access probes. Refer to FIG. 13.

b_{41} Diagnose	Sync Channel message	A Sync Channel message seen in State 4 indicates that the mobile station could not successfully get onto the traffic channel. Reasons for the message include: (1) the mobile station could have rejected the Channel Assignment message via an Access Channel Order message because it is no longer in the access state, or (2) due to loss of the paging channel in the access state (T_{40m}), or (3) because the Channel Assignment Message is received T_{42m} seconds after the Base Station Acknowledgment Order message, when the mobile station goes to the idle substate, (4) the mobile station could not get N_{5m} consecutive good frames within T_{50m} seconds of getting the Channel Assignment Message, (5) the mobile station did not receive the Base Station Acknowledgment Order message on the traffic channel within T_{51m} seconds of getting the Channel Assignment Message. Refer to FIG. 14.
f_{45}	first Base Station Acknowledgment Order message on the traffic channel	The mobile station jumped successfully onto the traffic channel. Disable T_{50m}, T_{51m}, start maintaining T_{5m}, T_{52m} timers, and keep track of the reverse traffic channel retransmission count (N_{1m}).

f_{55}, f_{65}	first Base Station Acknowledgment Order message on the traffic channel	Repetitions of Base Station Ack Order message on the traffic channel occur. Maintain T_{5m}, T_{52m} timers and keep track of the reverse traffic channel retransmission count (N_{1m}).
g_{56}, g_{66}	Traffic Channel messages other than the first Base Station Acknowledgment Order message	Maintain T_{5m}, T_{52m} timers and keep track of the reverse traffic channel retransmission count (N_{1m}).
h_{57}, h_{67}, h_{77}	Release Order message from mobile station or base station	The call is being released. Maintain T_{5m}, T_{52m} timers and keep track of the reverse traffic channel retransmission count (N_{1m}). Also, maintain the T_{55m} timer to see if there is a release state exit.
b_{51}, b_{61} Diagnose	Sync Channel message	A Sync Channel message seen in the log files while in States 5 or 6 indicates that the call has been terminated through other than normal release mechanisms. The possibilities include: (1) an Analog handoff, or (2) the mobile station received a Lock Until Power-Cycled Order message, or (3) the call was dropped due to a fade time out (T_{5m}), or (4) the call was dropped due to a waiting for order time out (T_{52m}=5s), or (5) the call was dropped due to an N_{1m} acknowledgment failure. Refer to FIG. 15.

b_{71} Diagnose	Sync Channel message	A Sync Channel message seen in State 7 indicates that the call ended with release orders. One of the following scenarios is possible: (1) a normal release occurred with a mutual exchange of Release Order messages between the mobile station and the base station, or (2) a release state time out (T_{55m}) occurred with the base station not sending a Release Order message in response to the one sent by the mobile station, or (3) the base station sent the first Release Order message, indicating in some cases a possible confusion at the base station end of call processing, or (4) a possible problem with mobile station when not it does not respond to the Release Order message from the base station. Refer to FIG. 16.
c_{13}	Base Station Acknowledgment Order message on the paging channel	The Base Station Ack Order message on the paging channel indicates that the logging could have missed the State 2 messages, such as an Origination message , a Page Response message, a Registration message (by way of access probes) for a new access attempt. The state transition c_{13} ensures the robustness of the state machine to insufficient logging. Another possibility is that the base station might be sending an acknowledgment for no apparent reason.

d_{24}	Channel Assignment message	Receipt of a Channel Assignment message after the access probes (sent on the access channel) indicates either that the base station did not send the acknowledgment order (i.e., the Base Station Acknowledgment Order on the PCH) or that the mobile station did not log the acknowledgment order. The state transition ensures the robustness of the state machine to insufficient logging.
d_{14}	Channel Assignment message	Receipt of the Channel Assignment message in State 1 may indicate that the base station is sending this message for no apparent reason or that insufficient logging of messages occurred.
f_{i5} $i = 1, 2, 3$	first Base Station Acknowledgment Order on the traffic channel	This message, seen in the log file while in State i, indicates that log file may not have logged the messages corresponding to States i+1 through 4. These state transitions ensure the robustness of the state machine to insufficient logging.
g_{i6} $i = 1, 2, 3, 4$	traffic channel messages other than the first Base Station Acknowledgment Order message	These messages, seen in the log file while in State i, indicate that log file may not have logged the messages corresponding to States i+1 through 5. These state transitions ensure the robustness of the state machine to insufficient logging.

h_{i7} $i = 1, 2, 3, 4$	Release Order from mobile station or base station	Release Orders, seen in the log file while in State i, indicate that log file may not have logged the messages corresponding to States i+1 through 6. These state transitions ensure the robustness of the state machine to insufficient logging.

b. Robust state transitions where logging is not perfect

The over-the-air messages are continuously transmitted from MS 110 to MDM 112 during the communications between MS 110 and BS 102. MS 110 has as its highest priority to keep the call up, i.e., to maintain communications with BS 102. Logging of the over-the-air signaling messages is secondary. Therefore, if MS 110 is not capable of transmitting these over-the-air messages to MDM 112 as quickly as it is communicating with BS 102, then the over-the-air messages may not be transmitted to MDM 112. In addition, after these over-the-air messages are received by MDM 112, it is possible that these messages are not stored in the log file as quickly as they are transmitted, causing a problem of overwriting of earlier messages. Again, this results in incomplete recordation of messages in the log file.

Consequently, the state transitions of the level A state diagram that assumes perfect logging, as illustrated in FIG. 5, is often inadequate for a reliable analysis. In order to compensate for this insufficient logging problem, the present invention provides the level B state diagram of FIG. 6. The level B state diagram improves the robustness of the state transitions by providing state transitions that do not actually exist in the real world.

i. d_{14}, d_{24}

For example, FIG. 6 illustrates a state transition from state 2 to state 4 by a dotted line. Referring to FIG. 5, whereas a state transition from state 4 to state 2 is acceptable, there is no acceptable state transition of the analysis tool from state 2 to state 4. However, the present invention is able to detect that a transition from state 2 to state 4 has occurred despite missing portions from the log file.

Suppose **d** message (Channel Assignment message) is received when the analysis tool is in state 2 and has transitioned to state 4. This indicates that (1) BS 102 is sending the Channel Assignment message for no apparent reason, or (2) BS 102 did not send a Base Station Ack Order message

on the PCH, or (3) that an insufficient logging problem has occurred where the Base Station Ack Order message has been sent, but has not been logged in the log file. The embodiment of FIG. 6 assumes that an insufficient logging problem has occurred and permits the transition. The same reasoning applies if a **d** message is received when the analysis tool is in state 1, with a robust state transition being permitted.

ii. c_{13}

If a **c** message (Base Station Ack Order message on the PCH) is viewed in the log file when the analysis tool is in state 1, and has transitioned to state 3, this indicates that messages corresponding to state transitions from states 2-3 may have been lost due to insufficient logging. The analysis tool permits the state transition to maintain robustness to the insufficient logging problem.

iii. f_{15}, f_{25}, f_{35}

If an **f** message (first Base Station Ack Order on the TCH) is viewed in the log file when the analysis tool transitions from states 1, 2, or 3 to state 5, this indicates that messages corresponding to state transitions from states 2-5, 3-5 or 4-5, respectively, may have been lost due to insufficient logging. The analysis tool permits these state transitions to maintain robustness to the insufficient logging problem.

iv. $g_{16}, g_{26}, g_{36}, g_{46}$

If a **g** message (TCH messages other than the first Base Station Ack Order on the TCH) is viewed in the log file when the analysis tool transitions from states 1, 2, 3 or 4 to state 6, this indicates that messages corresponding to state transitions from states 2-6, 3-6, 4-6, or 5-6, respectively, may have been lost due to insufficient logging. The analysis tool permits these state transitions to maintain robustness to the insufficient logging problem.

v. $h_{17}, h_{27}, h_{37}, h_{47}$

If an **h** message (Release Order message, from either BS 102 or MS 110) is viewed in the log file when the analysis tool transitions from states 1, 2, 3 or 4 to state 7, this indicates that messages corresponding to state transitions from states 2-7, 3-7, 4-7, or 5-7, respectively, may have been lost due to insufficient logging. The analysis tool permits these state transitions to maintain robustness to the insufficient logging problem.

c. Combined state diagram

FIG. 7 illustrates a level C state diagram. The level C state diagram of FIG. 7 combines the state diagram that assumes perfect logging of FIG. 5 and the state transitions that are designed to take care of insufficient logging of FIG. 6 into a single state diagram. In other words, the level C state diagram of FIG. 7 is robust to insufficient logging.

d. The timing function

At this point, it is important to denote the difference between how the mobile station uses timers and how the analysis tool of the present invention uses timers. As noted, the mobile station maintains timers to keep track of the various failure mechanisms. The analysis tool has a corresponding set of timers to detect and keep track of the failure mechanisms in the log files. The difference between the mobile station's timers and the analysis tool's timers lies in the way the analysis tool maintains its timers.

Whereas the mobile station uses a real-time running clock to increment/decrement its timers , the tool has no concept of a real-time clock. Instead, the analysis tool uses the time-stamp information provided with each message in the log file. Since there is nothing like a "running clock" in the mobile log files, the tool cannot increment or decrement its timers. It uses the end events to compute the effective values of the timers and determines if any of the timers have expired.

An example will illustrate the point. Referring to the level C state diagram of FIG. 7, when the tool is in state 3, where it has seen a Base Station Ack Order in the log for the mobile station's access attempts, the standard states that the mobile station should wait for the Channel Assignment message for T_{42m} seconds, after receiving the Base Station Ack Order on the PCH, before going back to idle substate 308 from its present access state 2. The way the mobile station implements this timer is by setting a timer to T_{42m} seconds on the receipt of the Base Station Ack Order message, and trickling the timer down until it reaches 0 seconds. If it does not see a Channel Assignment message within this time, it goes to the idle state.

On the other hand, the way the tool implements this is by checking for events which represent the receipt/non-receipt of the Channel Assignment message by the mobile station. These events can include, depending on the completeness of the logging mechanism, (1) a Channel Assignment message, (2) Access Channel Order messages, (3) a jump to TCH

message, or (4) system determination. The inventive analysis tool defines the time of receipt of the Base Station Ack Order message as t_3 and the time of the event indicating the receipt/non-receipt of the Channel Assignment message as t_4. The time difference between the two events, delta_t = t_4 - t_3, is compared with the constant T_{42m} as defined by the standard. If delta_t is less than T_{42m}, then the tool declares that the Channel Assignment message has been received by the mobile station within T_{42m}. If delta_t is greater than T_{42m}, then the tool declares that the Channel Assignment message has not been received in the desired time interval.

The other timers are maintained in the analysis tool in a similar manner by identifying the events that correspond to the receipt/non-receipt of certain messages. This indirect way of measuring time duration and triggering the expiration of timers is an important and novel step of the present invention.

e. Diagnostics

There are also diagnostic state transitions. A diagnostic state transition is a state transition from any state to either state 1 or access state 2. The diagnose state transitions include b_{11}, b_{21}, a_{22}, b_{31}, e_{32}, e_{42}, b_{41}, b_{51}, b_{61}, and b_{71}. Since state transitions to state 1 and state 2 are considered serious errors, the analysis tool uses the information collected during the previous state transitions to perform a detailed analysis for each diagnostic state transition. These are described in the sections below with reference to FIG. 8-16.

i. Diagnose b_{11}

FIG. 8 illustrates the flow chart used to make diagnostic decisions when the diagnose state transition b_{11} is made. This diagnosis occurs when an SCH message is received by MS 110 when it is the idle substate of state 1. In step 802, it is inquired why MS 110 has gone to the system determination substate of state 1 while monitoring the PCH.

In step 804, it is determined whether a Global Service Redirection message has been received. This message is sent by BS 102 to MS 110 to ask MS 110 to go to another system, such as a different CDMA system or another type of system (e.g., AMPS) altogether. Accordingly, if a Global Service Redirection message is received, it is logical to assume that the PCH has been dropped to go to another system.

If this is the case, then in step 806, a diagnostic message is printed indicating the condition. FIGs. 17A and 17B illustrate the diagnostic messages that the analysis tool can output. As indicated in step 806, diagnostic message 8.g is printed. In FIG. 17B, 8.g is line 1787, which states "Phone redirected to Analog in Paging Channel." Obviously, this message is for a switch to an analog system, and other messages are permissible.

If a Global Service Redirection message is not received, then the difference between t_exit and t_p is compared to the T_{30m} timer. The t_exit and t_p are times indicated by time stamps. The value t_p is the time that the last valid PCH message was seen in the log file. The value t_exit is the time when MS 110 went to the system determination substate. The mobile log indicates that MS 110 is in system determination by displaying that the MS 110 is using a pilot PN (pseudo random noise) signal with offset 0. The difference value t_exit-t_p indicates the time MS 110 was on the PCH without showing valid PCH messages. If the value is greater than T_{30m}, then MS 110 has abandoned the PCH for some reason. In other words, the phone waited for T_{30m} seconds before bailing out of the PCH.

If the condition in step 808 is satisfied, then control passes to step 810. In step 810, it is desired to determine the reason why MS 110 abandoned the PCH. Specifically, it is determined whether Ec/Io is above -15 dB and there is still no valid PCH message (which must be the case at this step). Ec/Io is the received bit energy to interferences ratio. A valid demodulable pilot is preferably above -15 dB. If Ec/Io is below -15 dB, it is unlikely that MS 110 can demodulate a signal on the PCH.

If in step 810 Ec/Io is greater than -15 dB, indicating a good signal to noise ratio, then control passes to step 812. In this case, there is no valid PCH message, despite the fact that the signal to noise ratio is good. This indicates that although an SCH message has been received from BS 102, the message included invalid or bad information, or that MS 110 has timing problems in jumping from the SCH to the PCH. Since the transition from the SCH (in SCH acquisition substate 306) to the PCH (in the idle substate 308) is called the timing change substate, this step indicates a timing change substate problem. As indicated in step 812, diagnostic message 1.a of FIG. 17A (line 1711) is printed.

If Ec/Io is not greater than -15 dB, as shown in step 814, then the loss of the PCH was not due to a poor pilot signal. In this case, a loss of PCH in the idle substate of state 1 is determined after a T_{30m} time out. As indicated

in step 814, here again diagnostic message 1.a of FIG. 17A (line 1711) is printed.

If in step 808, MS 110 does not wait for T_{30m} seconds before bailing out of the PCH, then control passes to step 816. In step 816, it is determined whether MS 110 slept just before the bail out occurred. In the IS-95-A protocol, there are many conditions in which MS 110 goes to "sleep" (i.e., reverts to the slotted mode). During such conditions, MS 110 is in an effective state of hibernation where it is not listening to incoming messages. MS 110 is in such a sleep condition in order to conserve energy. MS 110 and the BS 102 are always aware of when MS 110 will be in a sleep condition, so that BS 102 can schedule the MS 110 specific messages and times when MS 110 is awake. Here, it is determined whether the PCH channel is valid, yet the phone has come out of a sleep condition and has lost the pilot signal. This can occur if after MS 110 wakes up from a sleep condition, finding itself in a bad cell coverage area, and loses the pilot signal from BS 102.

If in step 816 it is determined that MS 110 was asleep just before the bailout of the PCH, then control passes to step 818. In step 818, it is determined that a "loss of acquisition after sleep" condition has occurred. As indicated in step 818, diagnostic message 1.c of FIG. 17A (line 1713) is printed, indicating that the PCH was dropped after sleep.

If it is determined in step 816 that MS 110 did not sleep just before exiting the PCH, then control is passed to step 820. In step 820, it is assumed that a new system exit has occurred. The following explains a new system exit.

In a typical situation, after MS 110 is powered up, it goes into the system determination substate 302, where the CDMA system is determined, followed by the pilot acquisition substate 304, where MS 110 sequentially runs through a list of prestored PNs, attempting to find a best pilot signal. After these earlier substates, which are known collectively as the system determination, MS 110 has acquired the pilot signal denoted by the PN value transmitted from BS 102.

During system determination, BS 102 also transmits to MS 110 a Neighbor List message. The Neighbor List message includes the PN values of all the base stations neighboring with BS 102. The Neighbor List message also contains configuration information for the pilot signals (PN values) of these neighboring base stations, which includes frequency information pertaining to these pilot signals.

When MS 110 travels outside of the cell coverage area 106 of BS 102, under normal circumstances a handoff occurs with another base station. In other words, MS 110 attempts to acquire the pilot signal of the other base station, which is stronger than the pilot signal received from BS 102. At this point, MS 110 normally uses only the PN sequences received from BS 102 in the previous Neighbor List message. This reduces the efforts of MS 110 in attempting to acquire the pilot signal of the new base station.

However, it is possible that MS 110 will pick up a pilot signal that it had not received in the Neighbor List message. Under this circumstance, MS 110 does a new system exit, where MS 110 will go back to the system determination and attempt to acquire the unrecognized pilot signal by sequentially running through all of the prestored PN sequences. In other words, during a new system exit, MS 110 will act as though it were just powered up. As indicated in step 820, diagnostic message 1.c of FIG. 17A (line 1713) is printed.

After each of steps 812 (timing change substate detection), 814 (loss of the PCH in the idle substate detection), 818 (loss of acquisition after sleep detection) or 820 (new system exit detection), control passes automatically to 822. After each of these steps, it is possible that a new pilot signal has been acquired by MS 110. Therefore, in step 822, it is determined whether the new pilot signal acquired by MS 110 is in the Neighbor List message of the old pilot signal previously acquired. If this condition is true, it indicates that one or more of the base stations have insufficient information with respect to their neighboring base stations. The analysis tool indicates neighbor list problems in its output, as discussed with respect to FIG. 18 below.

II. Diagnose b_{21}

FIG. 9 illustrates the flow chart used to make diagnostic decisions when the diagnose state transition $\mathbf{b_{21}}$ is made. This diagnosis occurs when an SCH message is received by MS 110 when it is in access state 2. In step 902, it is inquired why MS 110 has gone to system determination while MS 110 is sending an Origination message, a Page Response message, or a Registration message via access probes to BS 102 on the ACH.

In step 904, it is determined whether the total number of access probes sent is approximately equal to max_probes. Max_probes is the maximum number of access probes that can be sent as defined by the IS-95-A standard. The reason step 904 determines whether the number of probes sent approximately (rather than exactly) equals max_probes is because the

number of access probes actually sent may not have been recorded in the log file. This, again, is an example of the insufficient logging problem. Therefore, the number of access probes that are required to satisfy step 904 can be set based upon the prevalence of insufficient logging problems.

If in step 904 the total number of access probes approximately equals max_probes, then control passes to step 906. In step 906, it is determined that MS 110 has exhausted the maximum number of access probes, and the forward and reverse links are checked for a potential problem. Here, an attempt is made to determine why the maximum number of access probes has been exhausted. This may have been caused by a problem with the reverse link, where BS 102 cannot hear MS 110. This may also have been caused by a problem with the forward link, where BS 102 hears MS 110 and transmits a Base Station Ack Order message on the PCH, but MS 110 cannot hear this message, or if both the links are bad. As indicated in step 906, diagnostic message 2.a of FIG. 17A (line 1721) is printed.

If in step 904, the maximum number of access probes were not sent, then control passes to step 908. In step 908, MS 110 determines whether one of the following messages was received on the PCH: (1) Release Order, (2) Lock Until Power-Cycled Order, (3) Feature Notification with Release = 1, (4) Service Redirection, or (5) Registration Reject Order. The Release Order message indicates that BS 102 does not have sufficient resources to support the call. The Lock Until Power-Cycled Order message indicates to MS 110 that it is to lock and not transmit any other messages until further notification. This latter message is transmitted from BS 102 to MS 110 when BS 102 determines that MS 110 is malfunctioning, resulting in uncontrolled interference in the system. A Service Redirection message is transmitted by BS 102 to MS 110 when BS 102 is redirecting the service to another base station. This may occur, for example, when BS 102 has insufficient resources to support MS 110. A Registration Reject Order message occurs when BS 102 indicates to MS 110 that it is rejecting the attempt by MS 110 to register in its system.

If any of the messages of step 908 are received, then control passes to step 922. In step 922, MS 110 and the analysis tool transition back to the system determination substate. As indicated in step 922, diagnostic messages 2.b, 2.e, 8.e, 8.f, or 7.b of FIG. 17A and 17B (lines 1722, 1725, 1785, 1786, or 1772) are printed, respectively.

If none of the messages of step 908 are received, then control passes to step 910. In step 910, it is determined whether MS 110 received a Reorder Order message, a Registration Accepted Order message, or an Intercept Order message from BS 102 on the PCH. If any one of these messages is received in step 910, then in step 912 the analysis tool goes to the idle substate of state 1. As indicated in step 912, diagnostic messages 2.c, 7.a, or 2.d of FIG. 17A and 17B (lines 1723, 1771, or 1724) are printed.

After step 912, MS 110 is in the same condition as for diagnose b_{11}, i.e., in the idle substate of state 1, where an SCH message has been received from BS 102. Therefore, control passes to step 920, where the diagnose state transition for b_{11} of FIG. 8 is repeated.

If none of the messages of step 910 is received by MS 110, then control passes to step 914. In step 914, it is determined (1) whether MS 110 did an idle handoff or (2) if within a period of T_{42m} seconds following the transmission of the last access probe, MS 110 returned to the system determination substate.

If either of the conditions of step 914 are not satisfied, then control passes to step 918. In step 918, it is determined that BS 102 sent the Base Station Ack Order message on the PCH to MS 110, but this message was not logged due to an insufficient logging problem. Therefore, it is determined that the Channel Assignment message was not received within T_{42m} seconds after the last probe. The analysis tool transitions to the idle substate of state 1. As indicated in step 918, diagnostic message 3.b of FIG. 17A (line 1732) is printed. From step 918, control passes to step 920 and diagnose b_{11} is repeated, for the same reasons as noted for step 912.

If in step 914 it is determined that MS 110 did an idle handoff or it went to system determination within T_{42m} seconds, then control passes to step 916. In step 916, it is determined whether the PCH was lost in access state 2 and a T_{40m} time out has occurred. The analysis tool transitions to the idle substate of state 1. As indicated in step 916, diagnostic message 1.b of FIG. 17A (line 1712) is printed. From step 916, control passes to step 920 and diagnose b_{11} is repeated, for the same reasons as noted for step 912.

iii. Diagnose a_{22}

FIG. 10 illustrates the flow chart used to make diagnostic decisions when the diagnose state transition a_{22} is made. This diagnosis occurs when an Origination message, a Page Response message or a Registration message

access probe is transmitted from MS 110 to BS 102 over the ACH, when MS 110 is in access state 2. In step 1002, it is inquired why MS 110 is aborting the current access attempt and starting a new access attempt.

In step 1004, it is determined whether MS 110 received a Reorder Order message, a Registration Accepted Order message, or an Intercept Order message from BS 102 on the PCH. If any of these messages were received, then control passes to step 1006. In step 1006, MS 110 ends the previous access attempt and transitions to the idle substate of state 1. As indicated in step 1006, diagnostic messages 2.c, 7.a, or 2.d of FIG. 17A and 17B (lines 1723, 1771, or 1724) are printed, respectively.

If none of the messages of step 1004 were received by MS 110, then control passes to step 1008. In step 1008, it is determined whether the previous access attempt was an attempt at registration and the new access attempt is an Origination message or a Page Response message. Under the IS-95-A standard, a call origination from MS 110 or a call termination at MS 110 are given priority over attempts at registering MS 110. Therefore, it is considered normal for MS 110 to abort an attempt at registration if MS 110 transmits an Origination message (to originate a call from MS 110) or MS 110 transmits a Page Response message (to respond to a call terminating at MS 110). Therefore, if the condition in step 1008 is true, control passes to step 1010, where it is determined that MS 110 aborted the current registration procedure in order to respond to a page or to start a new call origination.

If the condition in step 1008 is not satisfied, then control passes to step 1012. In step 1012, it is determined whether MS 110 lost the PCH during access state 2. This condition is satisfied if a T_{40m} time out occurred. As indicated in step 1012, diagnostic message 1.b of FIG. 17A (line 1712) is printed.

iv. Diagnose b_{31}

FIG. 11 illustrates the flow chart used to make diagnostic decisions when the diagnose state transition b_{31} is made. This diagnosis occurs when an SCH message is received by MS 110 when it is in access state 3. In step 1102, it is inquired why MS 110 has gone to the system determination substate after getting the Base Station Ack Order message on the PCH.

In step 1104, the analysis tool determines whether one of the following messages was received: (1) Release Order, (2) Lock Until Power-Cycled Order, (3) Feature Notification with RELEASE=1, (4) Service

Redirection, or (5) Registration Reject Order on the PCH. The analysis tool transitions back to the system determination substate.

If any of these messages of step 1104 are received, then control passes to step 1106. In step 1106, MS 110 goes back to the system determination substate. As indicated in step 1106, diagnostic messages 2.b, 2.e, 8.e, 8.f, or 7.b of FIGs. 17A and 17B (lines 1722, 1725, 1785, 1786, or 1772) are printed, respectively.

If none of the messages of step 1104 are received, then control passes to step 1108. In step 1108, it is determined whether MS 110 received a Reorder Order message, a Registration Accepted Order message, or an Intercept Order message from BS 102 on the PCH. The analysis tool transitions back to the idle substate of state 1. If one of these messages was actually received in step 1108, then in step 1110 MS 110 goes to the idle substate of state 1. As indicated in step 1110, diagnostic messages 2.c, 7.a, or 2.d of FIGs. 17A and 17B (lines 1723, 1771, or 1724) are printed.

After step 1110, MS 110 is in the same condition as for diagnose $\mathbf{b_{11}}$, i.e., in the idle substate of state 1, where an SCH message has been received from BS 102. Therefore, control passes to step 1128, where the diagnose state transition for $\mathbf{b_{11}}$ of FIG. 8 is repeated.

If none of the messages of step 1108 are received, then control passes to step 1112. In step 1112, it is determined whether MS 110 did an idle hand-off or whether MS 110 did not see any valid PCH messages for T_{40m} seconds. Here, an attempt is made to determine why MS 110 bailed out of the PCH.

If the condition in step 1112 is satisfied, then control passes to step 1114. In step 1114, it is determined whether the bail-out of the PCH occurred within T_{42m} seconds after MS 110 received the Base Station Ack Order message on the PCH message. If the condition in step 1114 is satisfied, i.e., a T_{42m} time out did not occur, then control passes to step 1116.

In step 1116, where it has already been determined that a T_{42m} time out did not occur, it is concluded that MS 110 lost the PCH in access state 3 and a T_{40m} time out occurred. The analysis tool transitions to the idle substate of state 1. As indicated in step 1116, diagnostic message 1.b of FIG. 17A (line 1712) is printed.

If the condition in step 1114 is not satisfied, indicating that MS 110 bailed out of the PCH, but not within T_{42m} seconds after receiving a Base Station Ack Order message on the PCH, then control passes to step 1118. In

step 1118, it is concluded that MS 110 was in access state 3, but did not receive a Channel Assignment message within T_{42m} seconds after the Base Station Ack Order message on the PCH was received. The analysis tool transitions to the idle substate of state 1. As indicated in step 1118, diagnostic message 3.b of FIG. 17A (line 1732) is printed.

After steps 1116 and 1118, MS 110 is in the same condition as for a diagnose b_{11}, i.e., in the idle substate of state 1, where an SCH message has been received from BS 102. Therefore, control passes to step 1128, where diagnose state transitions for b_{11} of FIG. 8 are repeated.

If in step 1112 an idle handoff did not occur and one or more valid PCH messages were received within T_{40m} seconds, then control passes to step 1120. In step 1120, it is desired to determine whether a T_{42m} time out occurred. In this case, time stamps are used in order to determine this condition. The value t_exit is the time stamp for when MS 110 attempts to go to the system determination substate, which is the time the searcher is first seen to be using PN = 0. The value t_3 is the time stamp for when a Base Station Ack Order message on the PCH is first received, i.e., the entry time of MS 110 into access state 3.

The difference between t_exit and t_3 represents the time between when MS 110 entered access state 3 and when an SCH message was received. If the value of this difference is greater than T_{42m} seconds, then control passes to step 1118. In step 1118, it is determined that a T_{42m} time out occurred. Namely, it is determined that a Channel Assignment message was not received within T_{42m} seconds after a Base Station Ack Order message on the PCH was received. Again, the analysis tool transitions to the idle substate of state 1, diagnostic message 3.b of FIG. 17A (line 1732) is printed, and control passes to step 1128, where diagnose state transitions for b_{11} of FIG. 8 are repeated.

However, if the condition in step 1120 is not satisfied, indicating that a T_{42m} time out did not occur, then control passes to step 1122. In step 1122, it is determined whether the value t_exit - t_p is between T_{50m} seconds and T_{51m} seconds. The value t_p is a time stamp of the last valid PCH message seen in the log file. Therefore, the value t_exit-t_p is the difference in time between when the last valid PCH message was seen in the log file and when the SCH message was seen in the log file (i.e., when MS 110 transitioned back to the system determination substate).

Normally, when a Channel Assignment message is received, MS 110 transitions to "jump to TCH" state 4, where MS 110 jumps to the TCH and begins maintaining the T_{50m} and T_{51m} timers. If N_{5m} valid null frames are received over the TCH from BS 102 within T_{50m} seconds, then MS 110 begins transmitting null frames to BS 102 in order to establish the reverse TCH. Subsequently, if MS 110 receives the Base Station Ack Order message on the TCH from BS 102 within T_{51m} seconds, then it jumps to state 5. It must be remembered that in step 1122, an SCH message has been received even though no T_{40m} time out or T_{42m} time out has occurred. Accordingly, the analysis tool determines that MS 110 was actually in jump to TCH state 4, and no Channel Assignment message was received because of an insufficient logging problem.

If the condition in step 1122 is satisfied, then control passes to step 1124, where it is determined that the Channel Assignment message was received but not logged. It is also determined that a TCH initialization failure occurred, because N_{5m} good frames were not seen in the log file within T_{50m} seconds after MS 110 jumped to the TCH. As indicated in step 1124, diagnostic message 3.a of FIG. 17A (line 1731) is printed.

If the condition in step 1122 is not satisfied, it is assumed that the time between when the last valid PCH message was seen in the log file and when the SCH message was received is greater than T_{51m} seconds. Again, like in step 1126, it is determined that a Channel Assignment message was received but was not logged. Here, however, it is determined that the Base Station Ack Order message on the TCH did not occur within T_{51m} seconds after MS 110 jumped to the TCH. As indicated in step 1126, diagnostic message 3.c of FIG. 17A (line 1733) is printed.

v. Diagnose e_{32}

FIG. 12 illustrates the flow chart used to make diagnostic decisions when the diagnose state transition e_{32} is made. This diagnosis occurs when an Origination message, a Page Response message, or a Registration message access probe is transmitted from MS 110 to BS 102 over the ACH when MS 110 is in access state 3. In step 1202, it is inquired why MS 110 is starting a new access attempt after receiving the Base Station Ack Order message on the PCH message for the current access attempt. In other words, an attempt is made to determine why MS 110 is starting a new access attempt while awaiting a Channel Assignment message.

In step 1204, it is determined whether MS 110 received a Reorder Order message, a Registration Accepted Order message, or an Intercept Order message from BS 102 on the PCH. If any one of these messages is received, meaning that the condition of step 1204 is satisfied, then control passes to step 1206. In step 1206, MS 110 ends the previous access attempt. A transition back to the idle substate of state 1 occurs. As indicated in step 1206, diagnostic messages 2.c, 7.a, or 2.d of FIG. 17A and 17B (lines 1723, 1771, or 1724) are printed.

If none of the messages of step 1204 is received by MS 110, then control passes to step 1208. In step 1208, it is determined whether either (1) MS 110 performed an idle hand-off, or (2) during the T_{42m} timeout period (i.e., within T_{42m} seconds after MS 110 received a Base Station Ack Order message on the PCH), no valid PCH messages were received (a T_{40m} time out occurred).

If the condition in step 1208 is satisfied, then control passes to step 1210. In step 1210, it is determined that the PCH was lost in the access state 3 due to a valid T_{40m} time out. The analysis tool transitions to the idle substate of state 1. As indicated in step 1210, diagnostic message 1.b of FIG. 17A (line 1712) is printed.

If the condition in step 1208 is not satisfied, then control passes to step 1212. In step 1212, it is determined that MS 110 failed to receive a Channel Assignment message within T_{42m} seconds after the Base Station Ack Order message was received. The analysis tool transitions to the idle substate of state 1. As indicated in step 1212, diagnostic message 3.b of FIG. 17A (line 1732) is printed.

vi. Diagnose e_{42}

FIG. 13 illustrates the flow chart used to make diagnostic decisions when the diagnose state transition e_{42} is made. This diagnosis occurs when an Origination message, a Page Response message or a Registration message access probe is transmitted from MS 110 to BS 102 over the PCH when MS 110 is in jump to the TCH state 4.

In step 1302, it is inquired why MS 110 is starting a new access attempt after receiving the Channel Assignment message for the current access attempt. In step 1304, MS 110 transmits an Access Channel Order message to BS 102, rejecting the current Channel Assignment message.

In step 1306, it is determined whether the Channel Assignment message was received T_{42m} seconds after the Base Station Ack Order message on the PCH was received from BS 102. If this condition is satisfied, indicating that a T_{42m} timeout occurred, then control passes to step 1308.

In step 1308, it is determined that the Channel Assignment message was received after a T_{42m} timeout occurred, meaning that the Channel Assignment message was not received within T_{42m} seconds after the Base Station Ack Order message on the PCH was received. As indicated in step 1308, diagnostic message 3.b of FIG. 17A (line 1732) is printed.

If the Channel Assignment message is not received T_{42m} seconds after the Base Station Ack Order message on the PCH is received, then control passes to step 1310. In step 1310, it is determined that MS 110 may have lost the PCH while in the access state, as determined by a T_{40m} timeout. The analysis tool transitions back to the idle substate of state 1.

vii. Diagnose b_{41}

FIG. 14 illustrates the flow chart used to make diagnostic decisions when the diagnose state transition b_{41} is made. This diagnosis occurs when an SCH message is received by MS 110 when it is in jump to TCH state 4. In step 1402, it is inquired why MS 110 has gone to system determination substate after receiving the Channel Assignment message for the current access attempt.

In step 1404, it is determined whether MS 110 has transmitted an Access Channel Order message rejecting the Channel Assignment message. If the condition in step 1404 is not satisfied, control passes to step 1406.

In step 1406, it is determined whether the value t_exit - t_p is between T_{50m} seconds and T_{51m} seconds. The value t_exit is the time stamp for when MS 110 attempts to go to the system determination state (i.e., when the searcher first shows that MS 110 is using PN=0). The value t_4 is the time stamp for when the Channel Assignment message is first received, i.e., the entry time of MS 110 into jump to TCH state 4. The difference between t_exit and t_4 represents the time between when MS 110 entered jump to the TCH state 4 and the SCH message was received. Normally, when a Channel Assignment message is received, a transition to state 4 occurs, where MS 110 jumps to the TCH and begins maintaining the T_{50m} and T_{51m} timers. If N_{5m} valid null frames are received over the TCH from BS 102 within T_{50m} seconds, then MS 110 begins transmitting

null frames to BS 102 in order to establish the reverse TCH. Subsequently, if MS 110 received the Base Station Ack Order message on the TCH from BS 102 within T_{51m} seconds, then MS 110 transitions to state 5 (the first Base Station Ack message on the TCH state).

If the condition in step 1406 is satisfied, then control passes to step 1408. In step 1408, it is determined that a TCH initialization failure occurred, because N_{5m} good frames were not seen in the log file within T_{50m} seconds after MS 110 jumped to the TCH. As indicated in step 1408, diagnostic message 3.a of FIG. 17A (line 1731) is printed.

If the condition in step 1406 is not satisfied, then control passes to step 1410. In step 1410, like in step 1408, it is determined that a TCH initialization failure occurred. In this step, however, the TCH initialization failure occurred because MS 110 did not receive a Base Station Ack Order message on the TCH before a T_{51m} timeout occurred (i.e., within T_{51m} seconds after MS 110 jumped to the TCH). As indicated in step 1410, diagnostic message 3.c of FIG. 17A (line 1733) is printed.

If MS 110 did transmit an Access Channel Order message rejecting the Channel Assignment message in step 1404, then control passes to step 1412. In step 1412, it is determined whether the Channel Assignment message was received T_{42m} seconds after the Base Station Ack Order message was received on the PCH.

If the condition in step 1412 is not satisfied, then control passes to step 1416. In step 1416, it is determined that MS 110 may have lost the PCH while in the access state, as determined by a T_{40m} timeout. The analysis tool transitions back to the idle substate of state 1. As indicated in step 1416, diagnostic message 1.b of FIG. 17A (line 1712) is printed.

After step 1416, MS 110 is in the same condition as for diagnose b_{11}, i.e., in the idle substate of state 1, where an SCH message has been received from BS 102. Therefore, control passes to step 1420, where the diagnose state transition for b_{11} of FIG. 8 is repeated.

If the condition in step 1412 is not satisfied, then control passes to step 1418. In step 1418, it is determined that MS 110 did not receive a valid Channel Assignment message within T_{42m} seconds after it received the Base Station Ack Order message on the PCH, causing a transition back to the idle substate of state 1. As indicated in step 1418, diagnostic message 3.b of FIG. 17A (line 1732) is printed. As in step 1416, when MS 110 is in step 1418, it is in the idle substate of state 1 and has received an SCH message from BS

102. Accordingly, from step 1418, control passes to step 1420 and diagnose b_{11} is repeated.

viii. Diagnose b_{51}, diagnose b_{61}

FIG. 15 illustrates the flow chart used to make diagnostic decisions when the diagnose state transitions b_{51} and b_{61} are made. These diagnoses occur when an SCH message is received by MS 110 when it is in state 5 (the first Base Station Ack Order message on TCH state) or in state 6 (the TCH messaging state), respectively. In step 1502, it is inquired why the call was terminated through other than normal release mechanisms.

In step 1504, it is determined whether MS 110 received either a Lock Until Power-Cycled Order message or an Analog Hand-Off Direction message. As noted, MS 110 receives the Lock Until Power-Cycled Order message when BS 102 detects that MS 110 is expending unnecessary power, resulting in uncontrolled interference to the system. An Analog Hand-Off Direction message can be received if MS 110 is a dual mode mobile station, where it can handle both CDMA and analog cellular services. The Analog Hand-Off Direction message, itself, indicates that MS 110 is to be handed-off from a CDMA system to an analog system.

If either of the messages of step 1504 is received, then control passes to step 1506. In step 1506, MS 110 transitions to the system determination substate, if a Lock Until Power-Cycled Order message was received, or alternatively MS 110 transitions to AMPS, if an Analog Hand-Off Direction message was received. As indicated in step 1506, diagnostic messages 4.c or 8.d of FIG. 17A and 17B (lines 1743 or 1784) are printed.

If neither of the messages of step 1504 are received, then control passes to step 1508. In step 1508, it is determined whether a T_{5m} fade timeout occurred, by comparing the value t_exit-t_f with T_{5m}. As noted, t_exit is the time stamp for when MS 110 attempts to go to the system determination substate (i.e., when an SCH message is received). The value t_f is the time stamp for when the last valid TCH message was received.

If the condition in step 1508 is satisfied, control passes to step 1510. In step 1510, the T_{5m} timeout is taken to show that the call was dropped because of a fade timeout. The fade timeout, or T_{5m} timeout, refers to the fade or loss of the forward TCH signal. As indicated in step 1510, diagnostic message 4.a of FIG. 17B (line 1741) is printed.

If a T_{5m} timeout did not occur in step 1508, then control passes to step 1512. In step 1512, if the call is an incoming call, then it is determined whether a T_{52m} timeout occurred with no Alert With Information message received. This timeout is determined by comparing T_{52m} to the value t_exit-t_f. If the condition in step 1512 is satisfied, then control passes to step 1514. In step 1514, it is determined that the call was dropped (i.e., the TCH was lost) because of a waiting for order substate timeout. As indicated in step 1514, diagnostic message 4.b of FIG. 17B (line 1742) is printed.

If the condition in step 1512 is not satisfied, then control passes to step 1516. In step 1516, it is determined whether an N_{1m} acknowledgment failure occurred. N_{1m} acknowledgment failure occurs when MS 110 has transmitted a message on the forward TCH that requires an acknowledgment on the reverse TCH N_{1m} times, but has not received such acknowledgment. In other words, N_{1m} acknowledgment indicates a poor reverse TCH connection. As indicated in step 1516, diagnostic message 4.d of FIG. 17B (line 1744) is printed.

ix. **Diagnose b_{71}**

FIG. 16 illustrates the flow chart used to make diagnostic decisions when the diagnose state transition b_{71} is made. This diagnosis occurs when an SCH message is received by MS 110 when it is in call end state 7. In step 1602, it is inquired which mechanism is being used for call termination.

In step 1604, it is determined whether MS 110 has transmitted to BS 102 a Release Order message requiring an acknowledgment, where no such acknowledgment response has been received from BS 102. In other words, it is determined whether a T_{55m} timeout has occurred. If the condition in step 1604 is satisfied, control passes to step 1606, where a release state timeout is determined to have occurred. As indicated in step 1606, diagnostic message 5.a of FIG. 17B (line 1751) is printed.

If the condition in step 1604 is not satisfied, then control passes to step 1608. In step 1608, it is determined that MS 110 and BS 102 exchange Release Order messages. Next, in step 1610, it is determined that a normal call termination has occurred. However, there is a minor exception. Normally, MS 110 sends the initial Release Order message to BS 102, which subsequently sends back a Release Order Ack (acknowledgment) message to MS 110. However, if BS 102 is the first to send a Release Order message, awaiting acknowledgment from MS 110, this may indicate possible

confusion in the algorithms that are implemented by BS 102. As indicated in step 1610, diagnostic message 6 of FIG. 17B (line 1760) is printed.

7. Outputs

The outputs of the analysis tool can be printed or viewed on any standard display. These outputs are described below.

a. Diagnostic messages

FIGs. 17A and 17B illustrate the diagnostic message histograms (referred to as "Pareto Analysis") that the analysis tool can output for cases. In this section of the output, the analysis tool displays histograms of different categories of cases that are diagnosed from the mobile log files. The output contains (1) a list of different case categories, (2) the number of times a given case has occurred in all the input files, (3) a percentage distribution of the case categories, and (4) the number of times a given case has occurred individually in each log file.

b. Case studies

FIG. 18 illustrates the format used by the analysis tool to output the trigger messages, which it has detected from the log files, into its case studies. Sections 1810, 1820, 1830 and 1840 respectively show the formats for SCH messages, PCH messages, ACH messages and TCH messages. As shown in section 1800, each message format has a time stamp section 1802, a pilot PN and pilot Ec/Io information section 1804, a message flow direction section 1806 (which uses different types of arrows, lines, etc. to uniquely define the direction of the message and the channel the message is transmitted over), a channel section 1808 (which includes layer two information), and a message section 1809.

Section 1812 shows a sample SCH message output. Time stamp 1813 shows when the SCH message was received by the mobile station, in hours (hh), minutes (mm), seconds (ss), and thousandths of a second (000). Section 1814 shows the pilot PN and Ec/Io of the signal. This is searcher information regarding the pilot. The searcher is an entity in the mobile station that is constantly looking for new pilot signals. Section 1815 shows that the message is transmitted over the SCH, in a direction from the base station (B) toward the mobile station (M). Section 1816 shows that the channel over which the message is transmitted is an SCH (Sync Channel). This field also includes layer two information, which includes such well known parameters as whether the message is an acknowledgment, whether

the message requires an acknowledgment, etc. Finally, section 1817 shows that the message is an SCH (Sync Channel) message.

A CDMA mobile station employs a rake receiver design. A rake receiver is a collection of multiple demodulator receiving units, called "fingers," that allow the mobile to simultaneously lock onto multiple signal paths (called the multipath) for improved diversity reception. On the SCH, PCH and ACH, the mobile station is allowed to lock onto the multipath from only one base station that has the highest signal energy. Hence, the messages on SCH, PCH and ACH are displayed with the base station pilot PN and Ec/Io in section 1814. However, on the TCH, the mobile station can simultaneously demodulate signals from more than one base station (called "soft handoff"). The soft handoff is, therefore, the mechanism by which the mobile station improves the signal quality through diversity reception of multiple signal paths from several base stations. In a "hard handoff," the mobile station "breaks" the connection with the old base station to "make" a new connection with a new base station. On a soft handoff, on the other hand, the mobile station "makes" a connection with a new base station before it "breaks" the connection with the old base station. Thus, soft handoff not only improves signal reception but also prevents a call from dropping. To reflect the soft handoff capability in the TCH, section 1814 displays up to three pilots the mobile station is demodulating on the TCH.

Section 1844 shows a sample finger information for a sample TCH signal, with the three fingers pointing respectively to PN1, PN2 and PN3.

FIG. 19 illustrates case studies performed for the log files M1517068.906 and M0222430.161. At the end of each case study, there are diagnostic notes to describe whether the call ended normally or has failures. For example, section 1927 shows that case 2 is a normal call termination; section 1910 shows that case 1 indicates a PCH problem. The notes indicating failures are the outputs of the diagnoses described above. For example, the note for case 1 indicates that the PCH was lost in the idle state, a T_{30m} timeout occurred, and provides the time stamp of the occurrence. This note is the same as diagnostic message 3.c of FIG. 17A (line 1711), but also includes the time stamp for convenience. The time stamps provided in the diagnostics at the end of each case are very valuable pointers into the mobile log files, if one wants to study the problem in a greater detail than that provided by the algorithm.

Referring to FIG. 19, the case studies also illustrate the searcher information and finger information. Section 1921 shows a Page Response message transmitted over the ACH, with the searcher reporting the pilot PN = 176, with Ec/Io of -6.6 dB. Section 1922 shows a Base Station Ack Order message transmitted over the forward TCH, with the first two fingers locked onto pilot PN = 176, and the third finger not assigned to any signal path. Section 1923 shows a Release Order transmitted over the forward TCH, with the fingers locked onto pilots 176, 168 and 172, respectively. Here, all three pilots are being locked onto by the fingers.

Many times the log file ends before the analysis tool sees a trigger message that would make it perform a diagnosis on a case. In such cases it is important to "force" the tool to print the diagnostics based on whatever information it has seen. These cases called "end cases" are appended with a warning message (shown in Section 1972) that warn the systems engineer that information collected might be insufficient, thereby resulting in a false alarm.

c. Additional observations

The analysis tool outputs additional observations to aid the systems engineer studying a cellular system. These outputs are listed in FIGs. 20A-20D in neighbor list problems section 2000 and general observations section 2010.

Neighbor list problems section 2000 illustrates neighbor list problems for the sample log file M1517068.906. Different base stations are uniquely identified with a unique PN offset. A mobile station keeps continuously searching for good pilots. The base station provides a list of it's neighbors to the mobile station, thereby assisting the mobile station to quickly hand off to the strongest base station. The Neighbor List message can have up to N_{8m} pilots. The choice of pilots to be included in the Neighbor List message becomes crucial for proper functioning of the mobile station. Typical problems in the neighbor list design include (a) missing neighbors, where the base station does not provide a complete neighbor list, (b) non-symmetric neighbors, where a base station A lists PN B as its neighbor, but base station B does not list PN A as its neighbor. It is important to locate such neighbor list problems to reduce the risk of the mobile station losing a call or service due to incorrect or insufficient information sent by the base station.

Sections 2002 and 2004 show neighbor list problems that actually occurred during a case. In section 2002, pilots PN 192 and PN 30 were determined to not be in each other's neighbor lists. In section 2004, pilots PN 174 and PN 354 were determined to not be symmetric neighbors, meaning that PN 174 is not in the neighbor list of PN 354, but PN 354 is in the neighbor list of PN 174. Section 2006 shows non-symmetric neighbors which did not actually cause a problem. The analysis tool determines these latter pairs by cross-checking the neighbor lists at the end of its analyses.

As noted, N_{1m} counts out if the mobile station keeps retransmitting reverse TCH messages N_{1m} times without any acknowledgment response from the base station. Section 2010 provides histograms for the number of times the mobile station retransmits on the reverse TCH before acknowledgment is received. This is shown for the first log file M1517068.906, the second log file (which in this example has the same name), and for the totals for both log files. This histogram helps in identifying a call drop due to N_{1m} acknowledgment failure. It also gives the forward-reverse link imbalance. If the mobile station is seen to be retransmitting a message many times before getting acknowledgment, then it can be suspected that the forward or the reverse link or both have a problem.

Section 2012 shows the handoff distributions. As is well known, in a CDMA system, the cellular coverage area of each base station is divided into three sectors, each sector representing one third of the coverage area (i.e., a 120 degree area). During a soft handoff, the mobile station is communicating with two sectors from two different base stations. During a softer-handoff, the mobile station is communicating with two different sectors of the same base stations. Section 2012 shows hand-off distributions on a percentage basis for (1) a one-way handoff, (2) a two-way soft handoff (2W-SF), (3) a two-way softer handoff (2W-SR), (4) a three-way soft handoff (3W-SF), (5) a three-way soft-to- softer handoff (3W-SF-SR), (6) a three-way softer handoff (3W-SR), (7) a hard handoff, and (8) other handoffs (four-way, five-way, or six-way). Section 2012 shows these distributions for the first and second log files, both individually and combined. This distribution is helpful in getting an idea about the amount of resources the mobile station is using or to compute the performance of two different handoff algorithms.

Section 2014 shows the handoff setup time statistics. When the mobile station desires to make a handoff, it sends a Pilot Strength

Measurement message to the base station, providing the strengths of the pilot signals it is receiving. In response, the base station sends back a Hand-Off Direction message, indicating the list of pilot signals the mobile station may be in handoff with. The lag in time between when the mobile station sends the Pilot Strength Measurement message and the base station sends back the Hand-Off Direction message is the handoff setup time. In section 2014, the following statistics are provided for the handoff setup times: (1) the mean (in seconds), (2) the standard deviation (in seconds), (3) the minimum handoff setup time (in seconds), (4) the maximum handoff setup time (in seconds), and the number of handoff setup times (i.e., the sample size). These statistics are provided for the log files, both individually and combined. This data gives an idea about the latency of the base station in granting a handoff that could lead to a call drop.

Section 2016 shows the call setup time statistics. The lag in time between when the mobile station sends the access probes (Origination message, Page Response message or Registration message) and when the base station sends back the Base Station Ack Order message on the TCH is the call setup time. In other words, the call setup time indicates how long it took to establish the call from the time the mobile station requested it and gives an idea about the latency of the base station in setting up the resources and sending a Channel Assignment message. In section 2016, the following statistics are provided for the call setup times: (1) the mean (in seconds), (2) the standard deviation (in seconds), (3) the minimum call setup time (in seconds), (4) the maximum call setup time (in seconds), and the number of call setup times (i.e., the sample size). These statistics are provided for the log files, both individually and combined.

Section 2018 shows the pilot acquisition time statistics. During the pilot channel acquisition substate 304, the mobile station is searching for a valid pilot signal. When the mobile station subsequently receives an SCH message, this indicates that the pilot signal has been acquired, and the mobile station transitions to the SCH substate 306. From the log file, it is not possible to determine when the mobile station went back to the system determination substate 302. However, the analysis tool uses the searcher information (indicating the current pilot signal PN value) to determine whether the mobile station went to system determination or not. Specifically, this is determined by when the pilot PN takes on a zero value. Therefore, the lag in time between when the searcher first shows PN = 0 to

when the base station sends the SCH message provides the duration of the pilot signal acquisition substate 304. In section 2018, the following statistics are provided for the length of the pilot signal acquisition: (1) the mean (in seconds), (2) the standard deviation (in seconds), (3) the minimum value (in seconds), (4) the maximum value (in seconds), and the total number (i.e., the sample size). These statistics are provided for the log files, both individually and combined. Long acquisition times seen in this data may indicate potential problems with network coverage and the MS 110 system determination algorithms.

Section 2020 shows the multipath statistics. The statistics of the number of fingers that are locked to a single pilot when the mobile station is demodulating only one pilot (such as when it is in idle state or in the TCH in a one-way handoff) are provided in this table. The mobile station logs show the finger information consisting of the PN, Ec/Io and PN position for all the fingers. The finger which has maximum Ec/Io is chosen as the reference finger and any other finger is counted as the multipath of a given PN if: (a) its Ec/Io is within 10 dB of the maximum Ec/Io of the reference finger and (b) its position is at least one chip away from that of the reference finger. The first condition helps in isolating a reasonably strong multipath that can contribute to the effective Ec/Io, while the second condition ensures that the finger counted as multipath is not demodulating the same path as that of the reference finger.

Section 2022 provides the number of "timing change substate" problems (i.e., when despite a valid pilot signal, the mobile station cannot jump properly to the PCH from the SCH). The jump from the SCH to the PCH is also called the "jump to Hyperspace."

Section 2024 provides all of the pilot signals demodulated by the mobile station. This list not only indicates the different PNs the mobile station has seen, but also gives an idea about the mobility of the mobile station in a log file. For example, if one sees as many as six pilots when the mobile station is stationary, then one could suspect a pilot pollution problem.

Section 2026 provides the histogram of the maximum number of access probes transmitted per call. The format [A,B] is provided, where A is the number of probes per call, and B is the frequency of the occurrence of the number A. This information, combined with other statistics like Ec/Io and

received power, gives an idea about the forward, reverse link performances and any imbalance between them.

Section 2028 shows the number of hard handoffs. Section 2030 shows the number of analog handoffs (i.e., the number of handoffs to an AMPS system from a CDMA system). Whenever the mobile station does a handoff, the base station sends a new list of neighbors in a Neighbor List Update message, obtained by combining the neighbor lists of all the base stations with which the mobile station is in hand off. Sometimes the base station includes its own pilot PN along with the neighboring PNs in the Neighbor List Update message, which can be a potential cause for confusing the mobile station and can also constitute a standard violation. Section 2032 indicates any such cases and gives the time-stamps of the Neighbor List Update Messages where such an incident occurred.

8. An Implementation of the Invention

As stated above, the invention may be implemented using hardware, software or a combination thereof and may be implemented in a computer system or other processing system. In fact, in one embodiment, the invention is directed toward a computer system capable of carrying out the functionality described herein. An example computer system 2102 is shown in FIG. 21. The computer system 2102 includes one or more processors, such as processor 2104. The processor 2104 is connected to a communication bus 2106. Various software embodiments are described in terms of this example computer system. After reading this description, it will become apparent to a person skilled in the relevant art how to implement the invention using other computer systems and/or computer architectures.

Computer system 2102 also includes a main memory 2108, preferably random access memory (RAM), and can also include a secondary memory 2110. The secondary memory 2110 can include, for example, a hard disk drive 2112 and/or a removable storage drive 2114, representing a floppy disk drive, a magnetic tape drive, an optical disk drive, etc. The removable storage drive 2114 reads from and/or writes to a removable storage unit 2118 in a well known manner. Removable storage unit 2118, represents a floppy disk, magnetic tape, optical disk, etc. which is read by and written to by removable storage drive 2114. As will be appreciated, the removable storage unit 2118 includes a computer usable storage medium having stored therein computer software and/or data.

In alternative embodiments, secondary memory 2110 may include other similar means for allowing computer programs or other instructions to be loaded into computer system 2102. Such means can include, for example, a removable storage unit 2122 and an interface 2120. Examples of such can include a program cartridge and cartridge interface (such as that found in video game devices), a removable memory chip (such as an EPROM, or PROM) and associated socket, and other removable storage units 2122 and interfaces 2120 which allow software and data to be transferred from the removable storage unit 2118 to computer system 2102.

Computer system 2102 can also include a communications interface 2124. Communications interface 2124 allows software and data to be transferred between computer system 2102 and external devices. Examples of communications interface 2124 can include a modem, a network interface (such as an Ethernet card), a communications port, a PCMCIA slot and card, etc. Software and data transferred via communications interface 2124 are in the form of signals which can be electronic, electromagnetic, optical or other signals capable of being received by communications interface 2124. These signals 2126 are provided to communications interface via a channel 2128. This channel 2128 carries signals 2126 and can be implemented using wire or cable, fiber optics, a phone line, a cellular phone link, an RF link and other communications channels.

Computer system 2102 can also includes a graphics pipeline 2130. The graphics pipeline comprises the hardware and software that take input commands and produce therefrom data in the format of pixels. The pixels are output to frame buffer 2132. Frame buffer 2132 varies from a simple buffer capable of storing two-dimensional images, to a state-of-the-art device capable of displaying textured, three-dimensional, color images. Scan-out device 2134 comprises rendering hardware that selectively reads the pixels from frame buffer 2132 and transmits the pixels to display 2136. Display 2136, comprising for example a cathode ray tube (CRT), provides a physical display of the pixels. The scan-out device 2134 and display 2136 comport in function with the sophistication of the frame buffer 2132.

In this document, the terms "computer program medium" and "computer usable medium" are used to generally refer to media such as removable storage device 2118, a hard disk installed in hard disk drive 2112, and signals 626. These computer program products are means for providing software to computer system 2102.

Computer programs (also called computer control logic) are stored in main memory and/or secondary memory 2110. Computer programs can also be received via communications interface 2124. Such computer programs, when executed, enable the computer system 2102 to perform the features of the present invention as discussed herein. In particular, the computer programs, when executed, enable the processor 2104 to perform the features of the present invention. Accordingly, such computer programs represent controllers of the computer system 2102.

In an embodiment where the invention is implement using software, the software may be stored in a computer program product and loaded into computer system 2102 using removable storage drive 2114, hard drive 2112 or communications interface 2124. The control logic (software), when executed by the processor 2104, causes the processor 2104 to perform the functions of the invention as described herein.

In another embodiment, the invention is implemented primarily in hardware using, for example, hardware components such as application specific integrated circuits (ASICs). Implementation of the hardware state machine so as to perform the functions described herein will be apparent to persons skilled in the relevant art(s).

In yet another embodiment, the invention is implemented using a combination of both hardware and software.

9. Conclusion

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the relevant art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

WE CLAIM:

CLAIMS

1. A method for performing an analysis of a wireless communication system for a test case, wherein a plurality of over-the-air messages are transmitted between a mobile station and one or more base stations in the wireless communication system, comprising:

detecting one or more of the over-the-air messages for the test case in a log file;

transitioning between two or more transition states in response to detection of trigger messages in said log file, said trigger messages being ones of said over-the-air messages;

collecting and analyzing information pertaining to the wireless communication system in each of said transition states; and

providing a record of said analysis based on said collected and analyzed information.

2. The method of claim 1, wherein said step of collecting and analyzing information further comprises:

determining whether there has been a loss of a paging channel.

3. The method of claim 2, wherein said step of determining whether there has been a loss of said paging channel further comprises one of:

determining whether the mobile station lost said paging channel when the mobile station was in an idle state;

determining whether the mobile station lost said paging channel when the mobile station was in an access state;

determining whether the mobile station lost said paging channel when the mobile station dropped said paging channel in a new system exit procedure; and

determining whether the mobile station lost said paging channel after said mobile station awakened from a slotted mode.

4. The method of claim 1, wherein said step of collecting and analyzing information further comprises:

determining whether there was an access attempt failure.

5. The method of claim 4, wherein said step of determining whether there was said access attempt failure further comprises one of:

determining whether the mobile station exhausted the number of access probes the mobile station was permitted to send; and

determining whether the mobile station received from one of the base stations any one of:

a release order message;

a reorder order message;

an intercept order message; and

a lock until power-cycled order message.

6. The method of claim 1, wherein said step of collecting and analyzing information further comprises:

determining whether there was a traffic channel initialization failure.

7. The method of claim 6, wherein said step of determining whether there was said traffic channel initialization failure further comprises one of:

determining whether the mobile station detected that a predetermined number of traffic channel frames was not received from one of the base stations within a predetermined period of time;

determining whether a valid channel assignment message was not received; and

determining whether a base station acknowledgment order message on said traffic channel was not received from one of the base stations.

8. The method of claim 1, wherein said step of collecting and analyzing information further comprises:

determining whether a call between the mobile station and one of the base stations was dropped.

9. The method of claim 8, wherein said step of determining whether said call between the mobile station and one of the base stations was dropped further comprises one of:

determining whether there was a fade in a forward traffic channel between one of the base stations and the mobile station;

determining whether a waiting for order timeout occurred;

determining whether a lock until power-cycled order message was received; and

determining whether the mobile station transmitted a message requiring an acknowledgment on a reverse traffic channel between one of the base stations and the mobile station and that no acknowledgment was received after said transmitted message was retransmitted a predetermined number of times.

10. The method of claim 1, wherein said step of collecting and analyzing information further comprises:

determining whether a release order message was not received by one of:

the mobile station; and

one of the base stations,

because a release state time out occurred.

11. The method of claim 1, wherein said step of collecting and analyzing information further comprises:

determining whether a call between the mobile station and one of the base stations ended normally.

12. The method of claim 1, wherein said step of collecting and analyzing information further comprises:

determining whether there was a registration procedure between the mobile station and one of the base stations.

13. The method of claim 12, wherein said step of determining whether there was said registration procedure between the mobile station and one of the base stations further comprises one of:

determining whether said registration procedure was successful;

determining whether said registration procedure was rejected;

determining whether said registration procedure was acknowledged by one of the base stations.

14. The method of claim 1, wherein said step of collecting and analyzing information further comprises one of:

determining whether a base station acknowledgment order was sent on a paging channel from one of the base stations to the mobile station without an access probe having been first transmitted from the mobile station to the one base station;

determining whether a channel assignment message was sent from one of the base stations to the mobile station when the mobile station was in an idle state;

determining whether the mobile station did not respond to a release order message that the mobile station received from one of the base stations;

determining whether the mobile station was handed off to an analog system;

determining whether the mobile station received a feature notification message with release equal to one from one of the base stations;

determining whether the mobile station received a service redirection message from one of the base stations;

determining whether the mobile station was redirected to an analog system while the mobile station was in a paging channel; and

determining whether the mobile station ignored a channel assignment message it received from one of the base stations.

15. The method of claim 1, wherein said step of collecting and analyzing information further comprises:

identifying one or more neighbor list management problems for the wireless communication system.

16. The method of claim 1, wherein said step of collecting and analyzing information further comprises:

determining one or more problems associated with retransmissions of messages over a reverse traffic channel between the mobile station and one of the base stations.

17. The method of claim 1, wherein said step of collecting and analyzing information further comprises:

determining a handoff distribution between the mobile station and the one or more base stations.

18. The method of claim 1, wherein said step of collecting and analyzing information further comprises:

determining handoff setup time statistics between the mobile station and the one or more base stations.

19. The method of claim 1, wherein said step of collecting and analyzing information further comprises:

determining call setup time statistics between the mobile station and the one or more base stations.

20. The method of claim 1, wherein said step of collecting and analyzing information further comprises:

determining pilot acquisition time statistics between the mobile station and the one or more base stations.

21. The method of claim 1, wherein said step of collecting and analyzing information further comprises:

determining multipath statistics between the mobile station and the one or more base stations.

22. The method of claim 1, wherein said step of collecting and analyzing information further comprises:

determining a number of pilot signals visited by the mobile station.

23. The method of claim 1, wherein said step of collecting and analyzing information further comprises one of:

determining a maximum number of access probes transmitted per each call in the wireless communication system.

24. The method of claim 1, wherein said step of collecting and analyzing information further comprises one of:

determining a number of hard handoffs in the wireless communication system; and

determining a number of analog handoffs to an AMPS system.

25. The method of claim 1, wherein said step of collecting and analyzing information further comprises:

determining one or more time stamps of when bad neighbor list update messages were received from the one or more base stations.

26. A performance analysis tool for performing an analysis of a wireless communication system for a test case, wherein a plurality of over-the-air messages are transmitted between a mobile station and one or more

base stations in the wireless communication system, the performance analysis tool comprising:

means for detecting one or more of the over-the-air messages for the test case in a log file;

means for transitioning between two or more transition states in response to detection of trigger messages in said log file, said trigger messages being ones of said over-the-air messages;

means for collecting and analyzing information pertaining to the wireless communication system in each of said transition states; and

means for providing a record of said analysis based on said collected and analyzed information.

27. The performance analysis tool of claim 26, further comprising:

means for determining whether there has been a loss of a paging channel.

28. The performance analysis tool of claim 27, wherein said means for determining whether there has been a loss of said paging channel further comprises one of:

means for determining whether the mobile station lost said paging channel when the mobile station was in an idle state;

means for determining whether the mobile station lost said paging channel when the mobile station was in an access state;

means for determining whether the mobile station lost said paging channel when the mobile station dropped said paging channel in a new system exit procedure; and

means for determining whether the mobile station lost said paging channel after said mobile station awakened from a sleep condition.

29. The performance analysis tool of claim 26, further comprising:

means for determining whether there was an access attempt failure.

30. The performance analysis tool of claim 29, wherein said means for determining whether there was said access attempt failure further comprises one of:

means for determining whether the mobile station exhausted the number of access probes the mobile station was permitted to send; and

means for determining whether the mobile station received from one of the base stations any one of:

a release order message;

a reorder order message;

an intercept order message; and

a lock until power-cycled order message.

31. The performance analysis tool of claim 26, further comprising:

means for determining whether there was a traffic channel initialization failure.

32. The performance analysis tool of claim 31, wherein said means for determining whether there was said traffic channel initialization failure further comprises one of:

means for determining whether the mobile station detected that a predetermined number of traffic channel frames was not received from one of the base stations within a predetermined period of time;

means for determining whether a valid channel assignment message was not received; and

means for determining whether a base station acknowledgment order message on said traffic channel was not received from one of the base stations.

33. The performance analysis tool of claim 26, further comprising:

means for determining whether a call between the mobile station and one of the base stations was dropped.

34. The performance analysis tool of claim 33, wherein said means for determining whether said call between the mobile station and one of the base stations was dropped further comprises one of:

means for determining whether there was a fade in a forward traffic channel between one of the base stations and the mobile station;

means for determining whether a waiting for order timeout occurred;

means for determining whether a lock until power-cycled order message was received; and

means for determining whether the mobile station transmitted a message requiring an acknowledgment on a reverse traffic channel between one of the base stations and the mobile station and that no acknowledgment

was received after said transmitted message was retransmitted a predetermined number of times.

35. The performance analysis tool of claim 26, further comprising:

means for determining whether a release order message was not received by one of:

the mobile station; and

one of the base stations,

because a release state time out occurred.

36. The performance analysis tool of claim 26, further comprising:

means for determining whether a call between the mobile station and one of the base stations ended normally.

37. The performance analysis tool of claim 26, further comprising:

means for determining whether there was a registration procedure between the mobile station and one of the base stations.

38. The performance analysis tool of claim 37, wherein said means for determining whether there was said registration procedure between the mobile station and one of the base stations further comprises one of:

means for determining whether said registration procedure was successful;

means for determining whether said registration procedure was rejected;

means for determining whether said registration procedure was acknowledged by one of the base stations.

39. The performance analysis tool of claim 26, further comprising:

means for determining whether a base station acknowledgment order was sent on a paging channel from one of the base stations to the mobile station without an access probe having been first transmitted from the mobile station to the one base station;

means for determining whether a channel assignment message was sent from one of the base stations to the mobile station when the mobile station was in an idle state;

means for determining whether the mobile station did not respond to a release order message that the mobile station received from one of the base stations;

means for determining whether the mobile station was handed off to an analog system;

means for determining whether the mobile station received a feature notification message with release equal to one from one of the base stations;

means for determining whether the mobile station received a service redirection message from one of the base stations;

means for determining whether the mobile station was redirected to an analog system while the mobile station was in a paging channel; and

means for determining whether the mobile station ignored a channel assignment message it received from one of the base stations.

40. The performance analysis tool of claim 26, further comprising:

means for identifying one or more neighbor list management problems for the wireless communication system.

41. The performance analysis tool of claim 26, further comprising:

means for determining one or more problems associated with retransmissions of messages over a reverse traffic channel between the mobile station and one of the base stations.

42. The performance analysis tool of claim 26, further comprising:

means for determining a handoff distribution between the mobile station and the one or more base stations.

43. The performance analysis tool of claim 26, further comprising:

means for determining handoff setup time statistics between the mobile station and the one or more base stations.

44. The performance analysis tool of claim 26, further comprising:

means for determining call setup time statistics between the mobile station and the one or more base stations.

45. The performance analysis tool of claim 26, further comprising:

means for determining pilot acquisition time statistics between the mobile station and the one or more base stations.

46. The performance analysis tool of claim 26, further comprising:
means for determining multipath statistics between the mobile station and the one or more base stations.

47. The performance analysis tool of claim 26, wherein said step of collecting and analyzing information further comprises:
means for determining a number of pilot signals visited by the mobile station.

48. The performance analysis tool of claim 26, wherein said step of collecting and analyzing information further comprises one of:
means for determining a maximum number of access probes transmitted per each call in the wireless communication system.

49. The performance analysis tool of claim 26, wherein said step of collecting and analyzing information further comprises one of:
means for determining a number of hard handoffs in the wireless communication system; and
means for determining a number of analog handoffs to an AMPS system.

50. The performance analysis tool of claim 26, wherein said step of collecting and analyzing information further comprises:
means for determining one or more time stamps of when bad neighbor list update messages were received from the one or more base stations.

51. A wireless communication system, comprising:
one or more base stations;
one or more mobile stations;
a performance analysis tool for performing an analysis of the wireless communication system for a test case, wherein a plurality of over-the-air messages are transmitted between a mobile station and the one or more base stations in the wireless communication system, the performance analysis tool comprising:
means for detecting one or more of the over-the-air messages for the test case in a log file;

means for transitioning between two or more transition states in response to detection of trigger messages in said log file, said trigger messages being ones of said over-the-air messages;

means for collecting and analyzing information pertaining to the wireless communication system in each of said transition states; and

means for providing a record of said analysis based on said collected and analyzed information.

52. The wireless communication system of claim 51, wherein the wireless communication system is any one of:

a CDMA system;

an AMPS system;

a TDMA system; and

a GSM system.

53. The wireless communication system of claim 51, wherein the wireless communication system is one of:

a digital wireless communication system;

an analog wireless communication system.

54. A computer program product for performing an analysis of a wireless communication system for a test case, wherein a plurality of over-the-air messages are transmitted between a mobile station and one or more base stations in the wireless communication system,

wherein said computer program product comprises a computer useable medium having computer program logic stored therein, said computer program logic comprises:

means for enabling a computer to detect one or more of the over-the-air messages for the test case in a log file;

means for enabling a computer to transition between two or more transition states in response to detection of trigger messages in said log file, said trigger messages being ones of said over-the-air messages;

means for enabling a computer to collect and analyze information pertaining to the wireless communication system in each of said transition states; and

means for enabling a computer to provide a record of said analysis based on said collected and analyzed information.

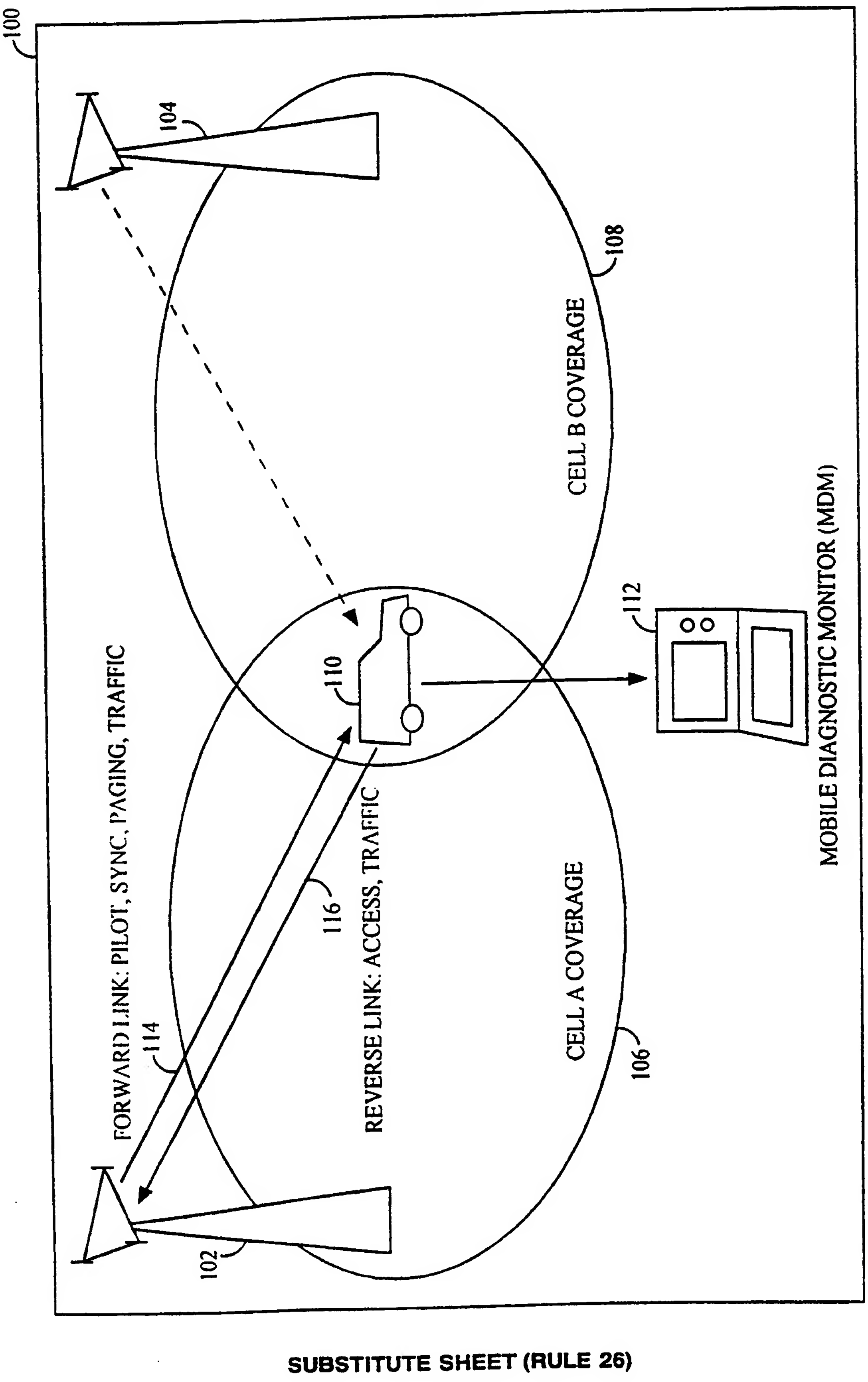
100
104
108
CELL B COVERAGE
112
MOBILE DIAGNOSTIC MONITOR (MDM)
110
FORWARD LINK: PILOT, SYNC, PAGING, TRAFFIC
114
116
REVERSE LINK: ACCESS, TRAFFIC
CELL A COVERAGE
106
102

FIG. 1

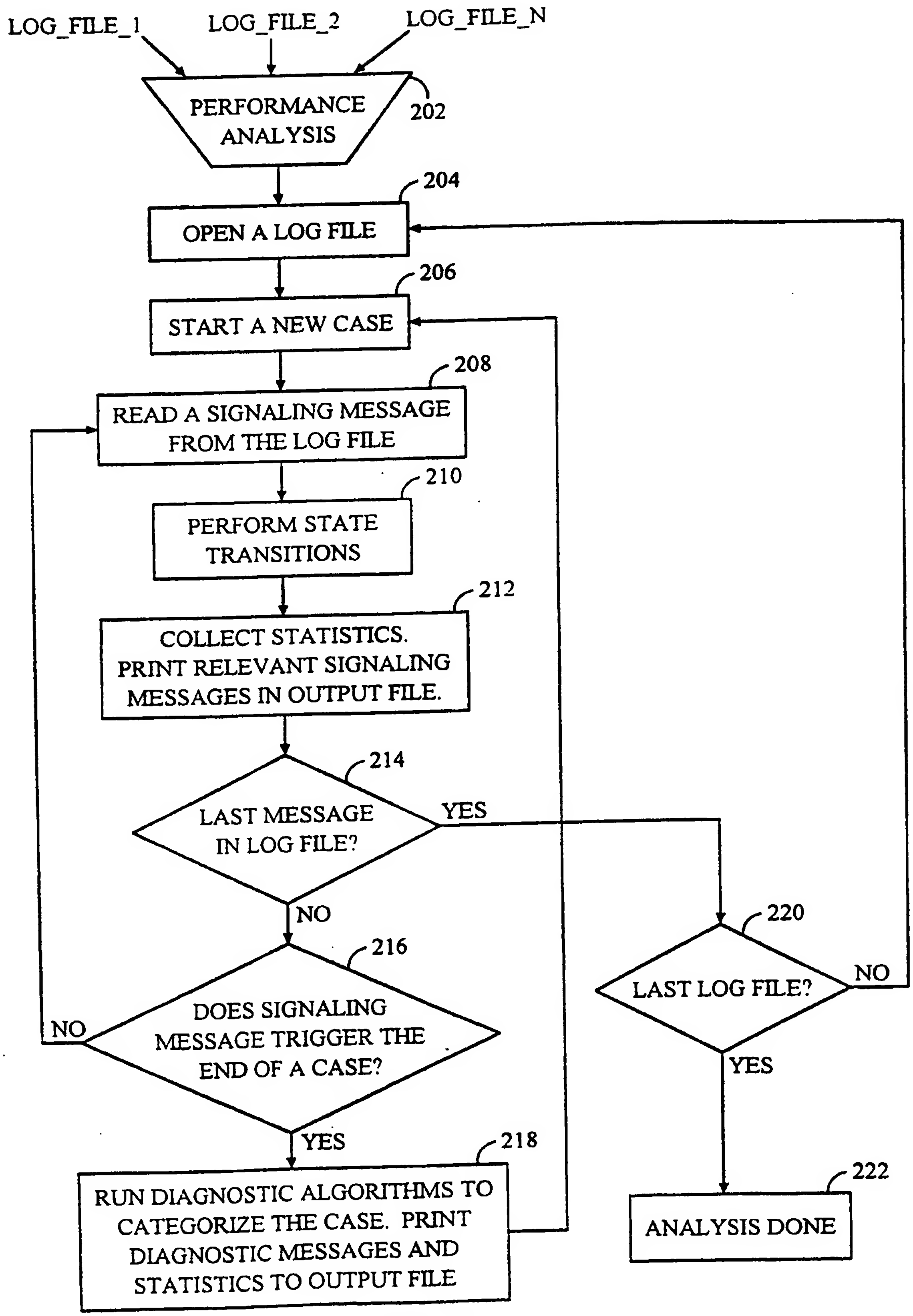
LOG_FILE_1
LOG_FILE_2
LOG_FILE_N
PERFORMANCE ANALYSIS
202
204
OPEN A LOG FILE
206
START A NEW CASE
208
READ A SIGNALING MESSAGE FROM THE LOG FILE
210
PERFORM STATE TRANSITIONS
212
COLLECT STATISTICS. PRINT RELEVANT SIGNALING MESSAGES IN OUTPUT FILE.
214
LAST MESSAGE IN LOG FILE?
YES
NO
216
DOES SIGNALING MESSAGE TRIGGER THE END OF A CASE?
NO
YES
218
RUN DIAGNOSTIC ALGORITHMS TO CATEGORIZE THE CASE. PRINT DIAGNOSTIC MESSAGES AND STATISTICS TO OUTPUT FILE
220
LAST LOG FILE?
NO
YES
222
ANALYSIS DONE

FIG. 2

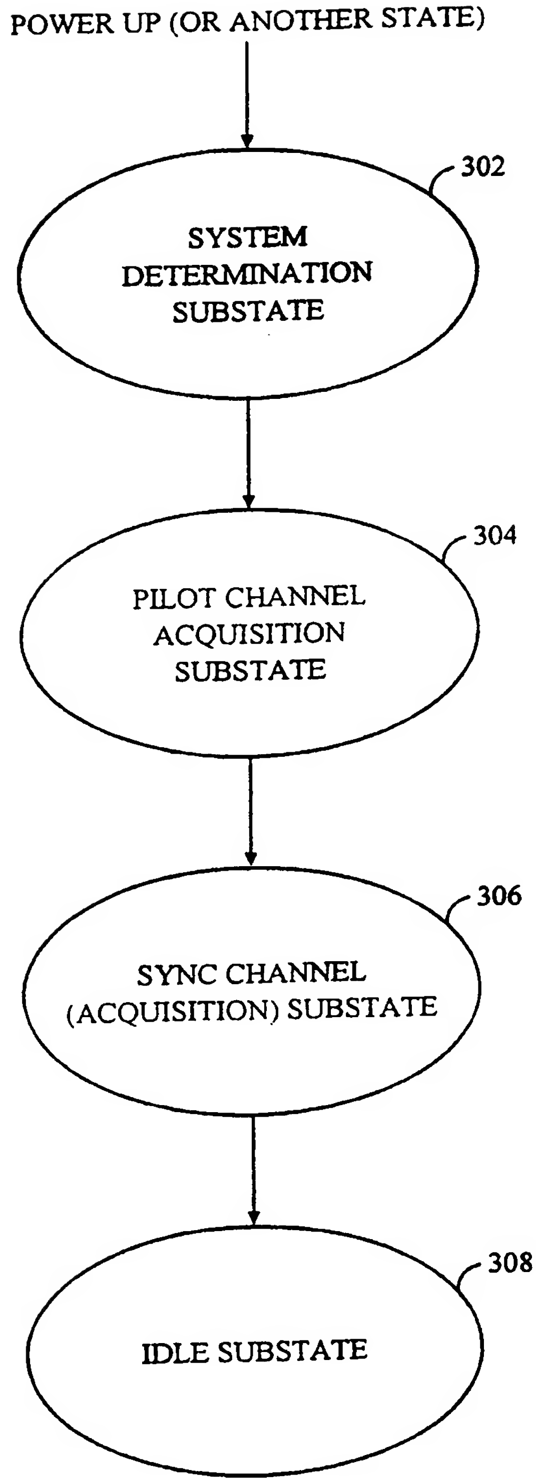
POWER UP (OR ANOTHER STATE)
302
SYSTEM DETERMINATION SUBSTATE
304
PILOT CHANNEL ACQUISITION SUBSTATE
306
SYNC CHANNEL (ACQUISITION) SUBSTATE
308
IDLE SUBSTATE

FIG. 3

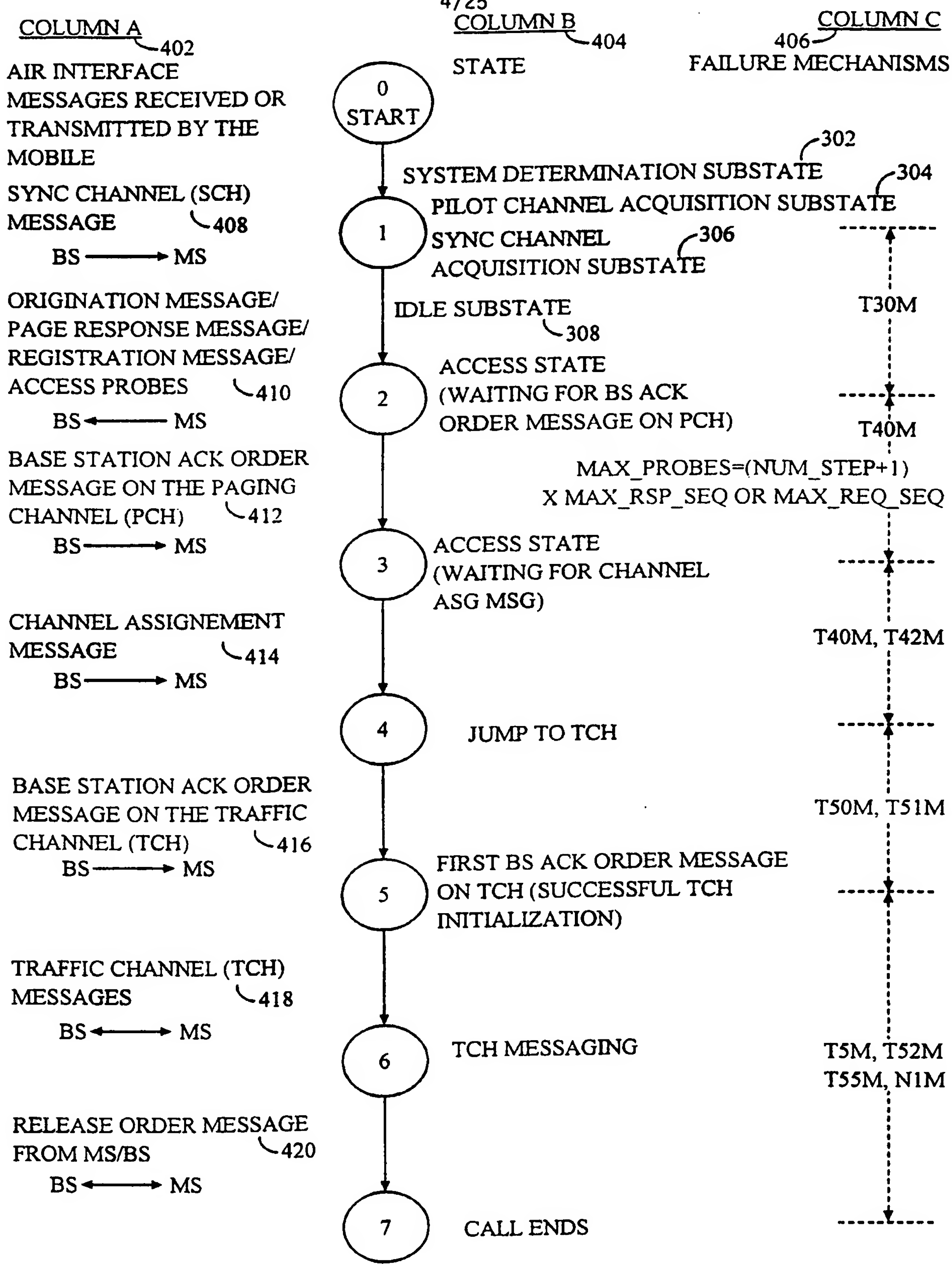
COLUMN A
402
AIR INTERFACE MESSAGES RECEIVED OR TRANSMITTED BY THE MOBILE
COLUMN B
404
STATE
COLUMN C
406
FAILURE MECHANISMS
0 START
302
SYSTEM DETERMINATION SUBSTATE
304
PILOT CHANNEL ACQUISITION SUBSTATE
SYNC CHANNEL (SCH) MESSAGE
408
BS → MS
1
SYNC CHANNEL ACQUISITION SUBSTATE
306
IDLE SUBSTATE
308
T30M
ORIGINATION MESSAGE/ PAGE RESPONSE MESSAGE/ REGISTRATION MESSAGE/ ACCESS PROBES
410
BS ← MS
2
ACCESS STATE (WAITING FOR BS ACK ORDER MESSAGE ON PCH)
T40M
MAX_PROBES=(NUM_STEP+1) X MAX_RSP_SEQ OR MAX_REQ_SEQ
BASE STATION ACK ORDER MESSAGE ON THE PAGING CHANNEL (PCH)
412
BS → MS
3
ACCESS STATE (WAITING FOR CHANNEL ASG MSG)
CHANNEL ASSIGNEMENT MESSAGE
414
BS → MS
T40M, T42M
4
JUMP TO TCH
BASE STATION ACK ORDER MESSAGE ON THE TRAFFIC CHANNEL (TCH)
416
BS → MS
T50M, T51M
5
FIRST BS ACK ORDER MESSAGE ON TCH (SUCCESSFUL TCH INITIALIZATION)
TRAFFIC CHANNEL (TCH) MESSAGES
418
BS ↔ MS
6
TCH MESSAGING
T5M, T52M
T55M, N1M
RELEASE ORDER MESSAGE FROM MS/BS
420
BS ↔ MS
7
CALL ENDS

FIG. 4

LEVEL A
THE STATE DIAGRAM
ASSUMING PERFECT
LOGGING

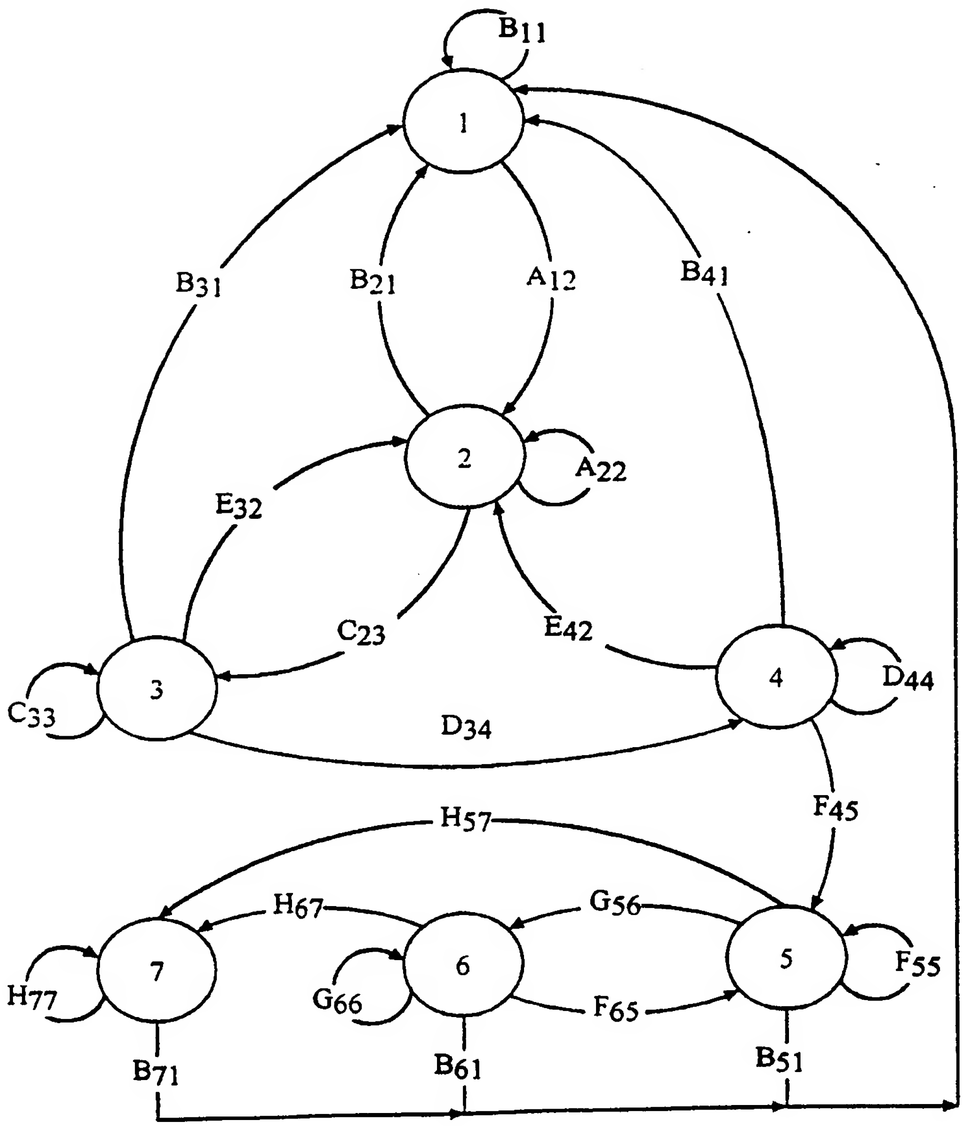

FIG. 5

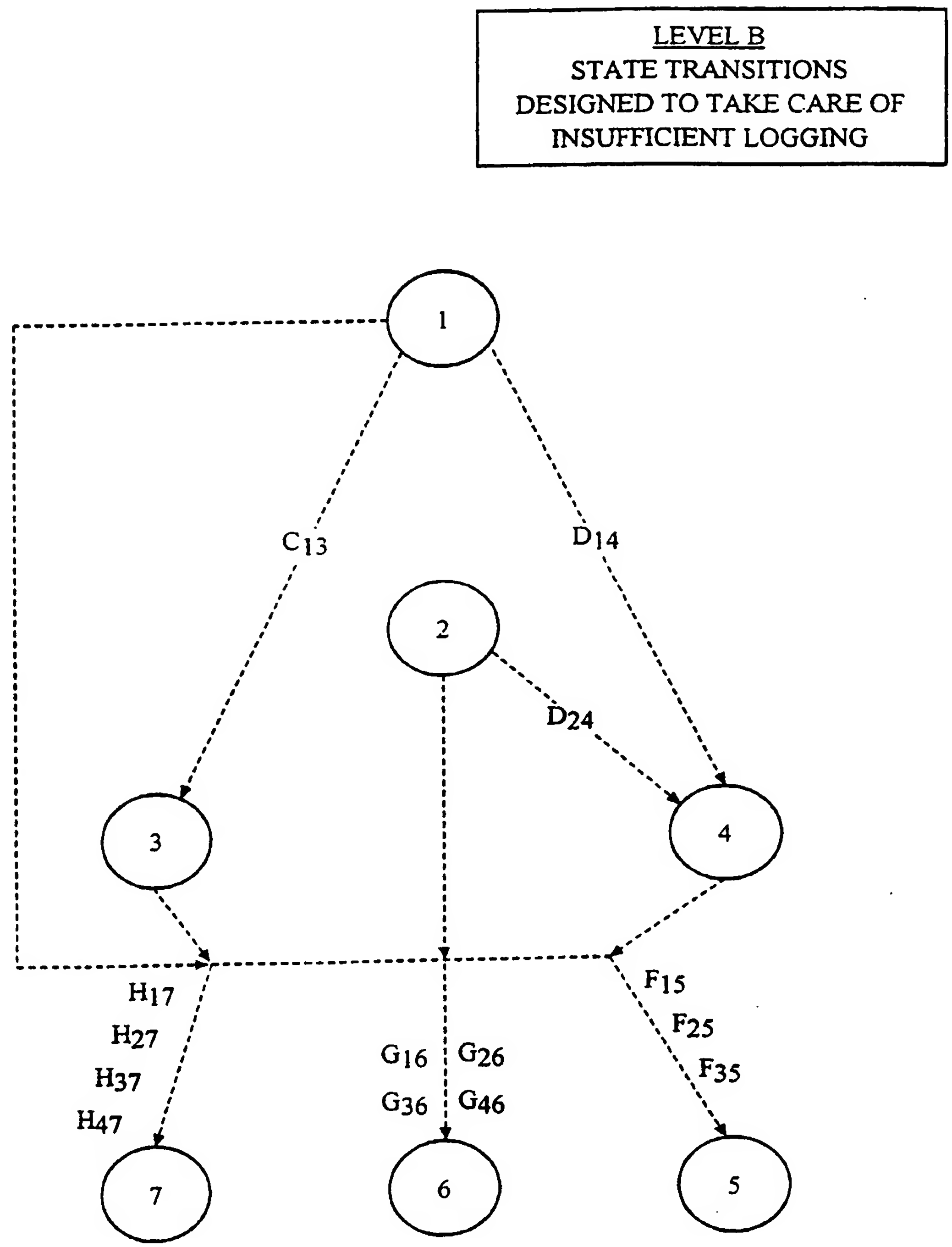
LEVEL B
STATE TRANSITIONS
DESIGNED TO TAKE CARE OF
INSUFFICIENT LOGGING
1
2
3
4
5
6
7
C13
D14
D24
H17
H27
H37
H47
G16
G26
G36
G46
F15
F25
F35

FIG. 6

LEVEL C
THE COMPLETE
STATE DIAGRAM
WHICH IS ROBUST TO
INSUFFICIENT LOGGING

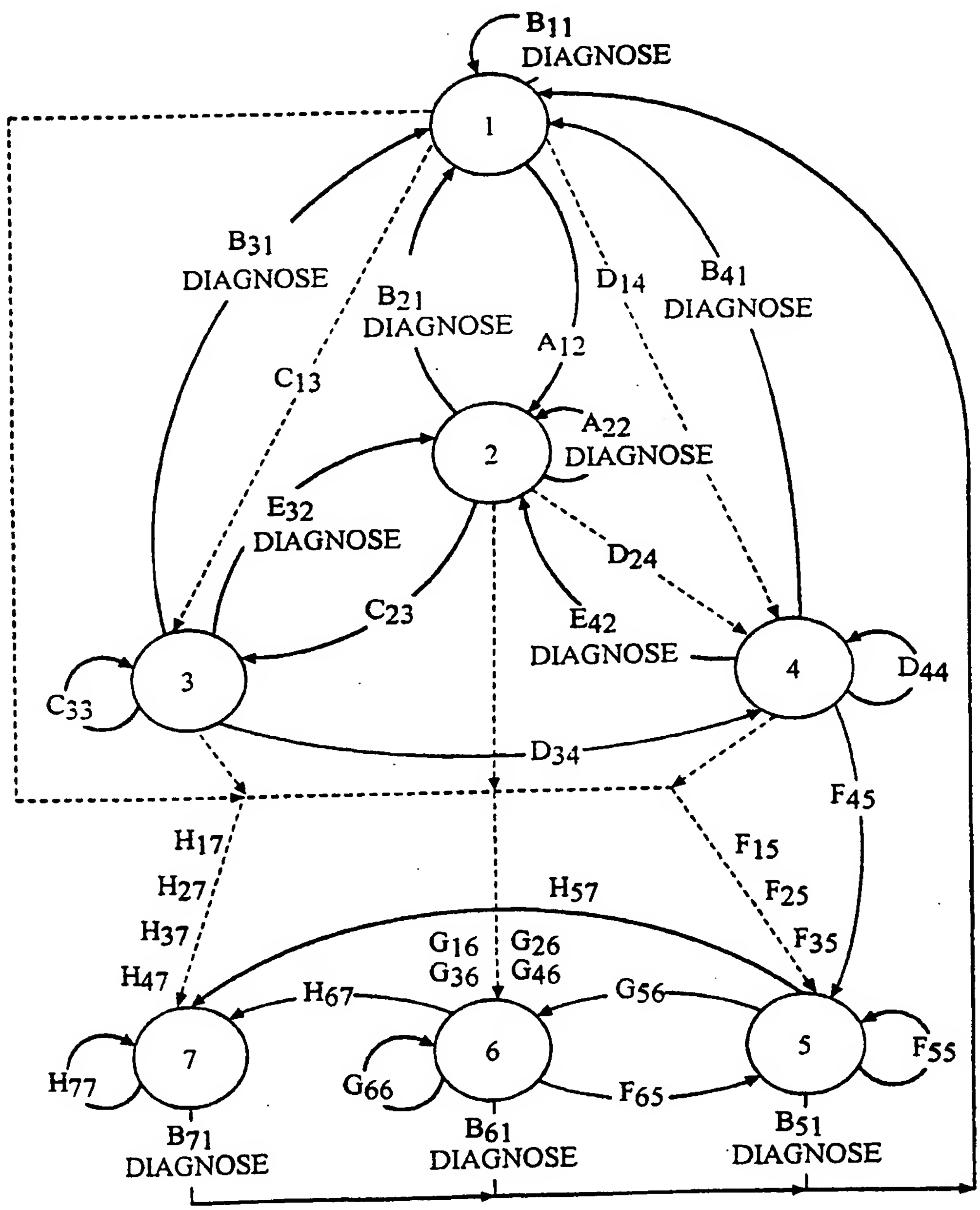

FIG. 7

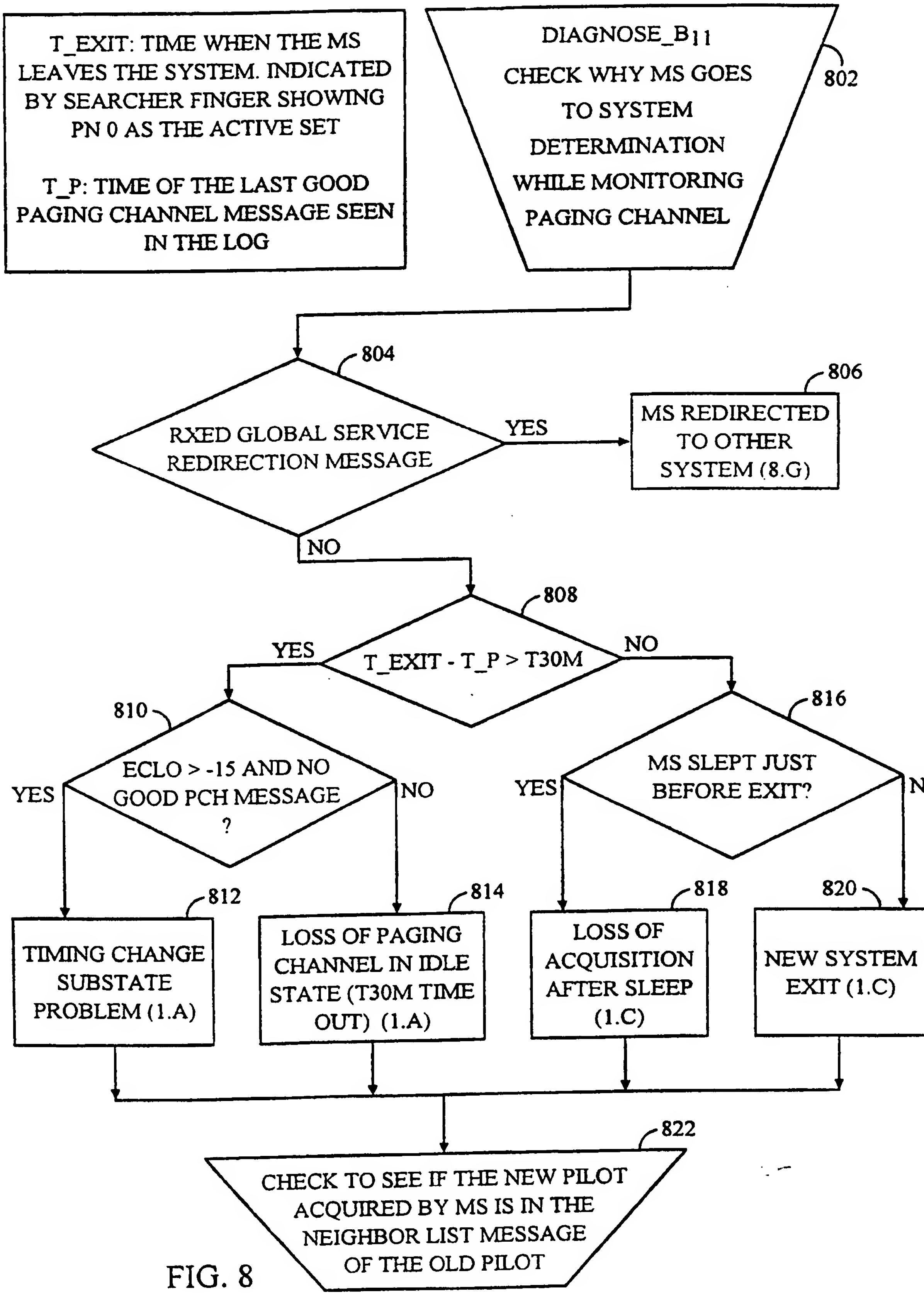
T_EXIT: TIME WHEN THE MS LEAVES THE SYSTEM. INDICATED BY SEARCHER FINGER SHOWING PN 0 AS THE ACTIVE SET
T_P: TIME OF THE LAST GOOD PAGING CHANNEL MESSAGE SEEN IN THE LOG
DIAGNOSE_B11
CHECK WHY MS GOES TO SYSTEM DETERMINATION WHILE MONITORING PAGING CHANNEL
802
804
RXED GLOBAL SERVICE REDIRECTION MESSAGE
YES
806
MS REDIRECTED TO OTHER SYSTEM (8.G)
NO
808
T_EXIT - T_P > T30M
YES
NO
810
ECLO > -15 AND NO GOOD PCH MESSAGE ?
YES
NO
816
MS SLEPT JUST BEFORE EXIT?
YES
NO
812
TIMING CHANGE SUBSTATE PROBLEM (1.A)
814
LOSS OF PAGING CHANNEL IN IDLE STATE (T30M TIME OUT) (1.A)
818
LOSS OF ACQUISITION AFTER SLEEP (1.C)
820
NEW SYSTEM EXIT (1.C)
822
CHECK TO SEE IF THE NEW PILOT ACQUIRED BY MS IS IN THE NEIGHBOR LIST MESSAGE OF THE OLD PILOT

FIG. 8

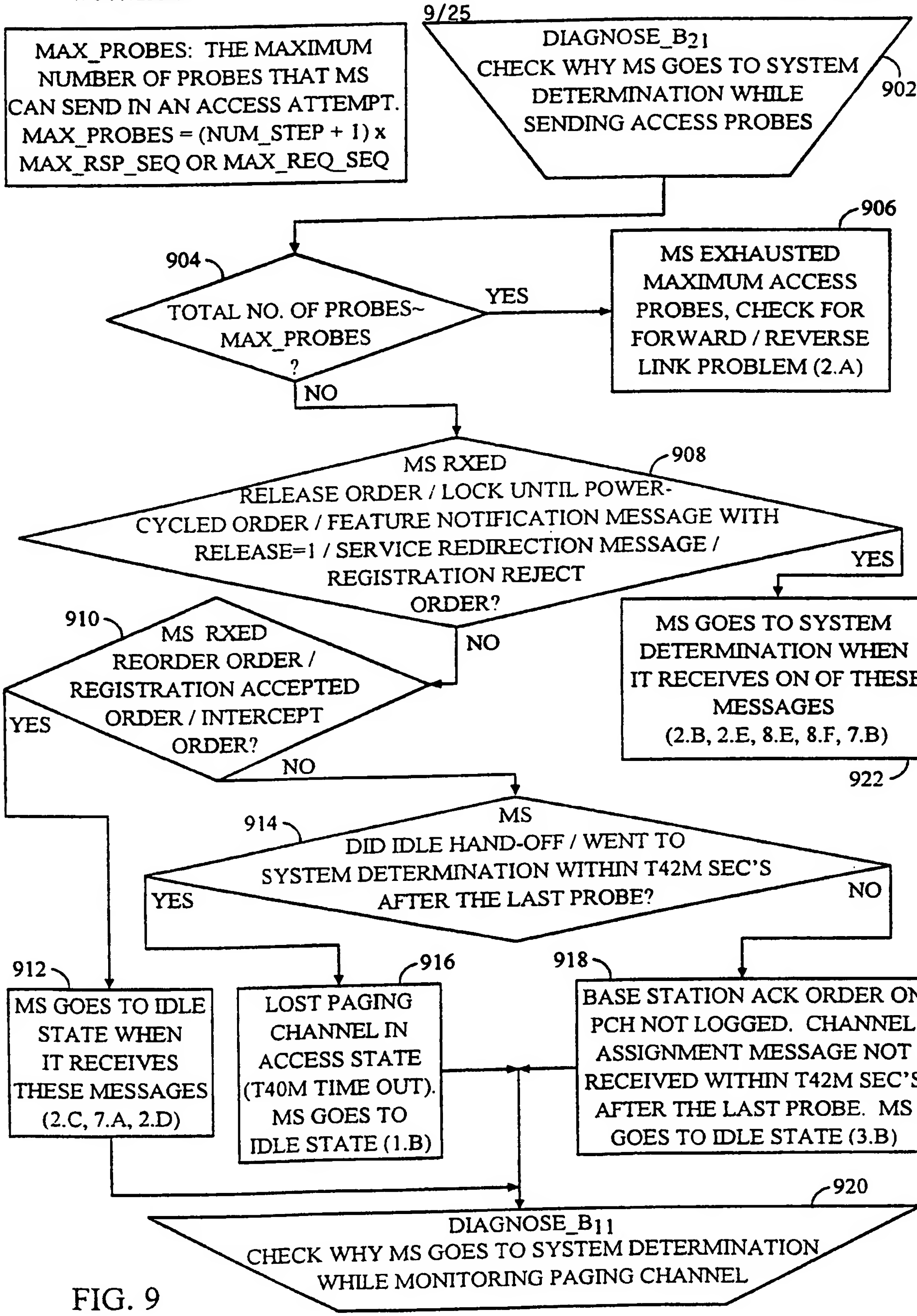
MAX_PROBES: THE MAXIMUM NUMBER OF PROBES THAT MS CAN SEND IN AN ACCESS ATTEMPT. MAX_PROBES = (NUM_STEP + 1) x MAX_RSP_SEQ OR MAX_REQ_SEQ
DIAGNOSE_B21 CHECK WHY MS GOES TO SYSTEM DETERMINATION WHILE SENDING ACCESS PROBES
902
904
TOTAL NO. OF PROBES~ MAX_PROBES ?
YES
NO
906
MS EXHAUSTED MAXIMUM ACCESS PROBES, CHECK FOR FORWARD / REVERSE LINK PROBLEM (2.A)
908
MS RXED RELEASE ORDER / LOCK UNTIL POWER-CYCLED ORDER / FEATURE NOTIFICATION MESSAGE WITH RELEASE=1 / SERVICE REDIRECTION MESSAGE / REGISTRATION REJECT ORDER?
YES
NO
MS GOES TO SYSTEM DETERMINATION WHEN IT RECEIVES ON OF THESE MESSAGES (2.B, 2.E, 8.E, 8.F, 7.B)
922
910
MS RXED REORDER ORDER / REGISTRATION ACCEPTED ORDER / INTERCEPT ORDER?
YES
NO
914
MS DID IDLE HAND-OFF / WENT TO SYSTEM DETERMINATION WITHIN T42M SEC'S AFTER THE LAST PROBE?
YES
NO
912
MS GOES TO IDLE STATE WHEN IT RECEIVES THESE MESSAGES (2.C, 7.A, 2.D)
916
LOST PAGING CHANNEL IN ACCESS STATE (T40M TIME OUT). MS GOES TO IDLE STATE (1.B)
918
BASE STATION ACK ORDER ON PCH NOT LOGGED. CHANNEL ASSIGNMENT MESSAGE NOT RECEIVED WITHIN T42M SEC'S AFTER THE LAST PROBE. MS GOES TO IDLE STATE (3.B)
920
DIAGNOSE_B11 CHECK WHY MS GOES TO SYSTEM DETERMINATION WHILE MONITORING PAGING CHANNEL

FIG. 9

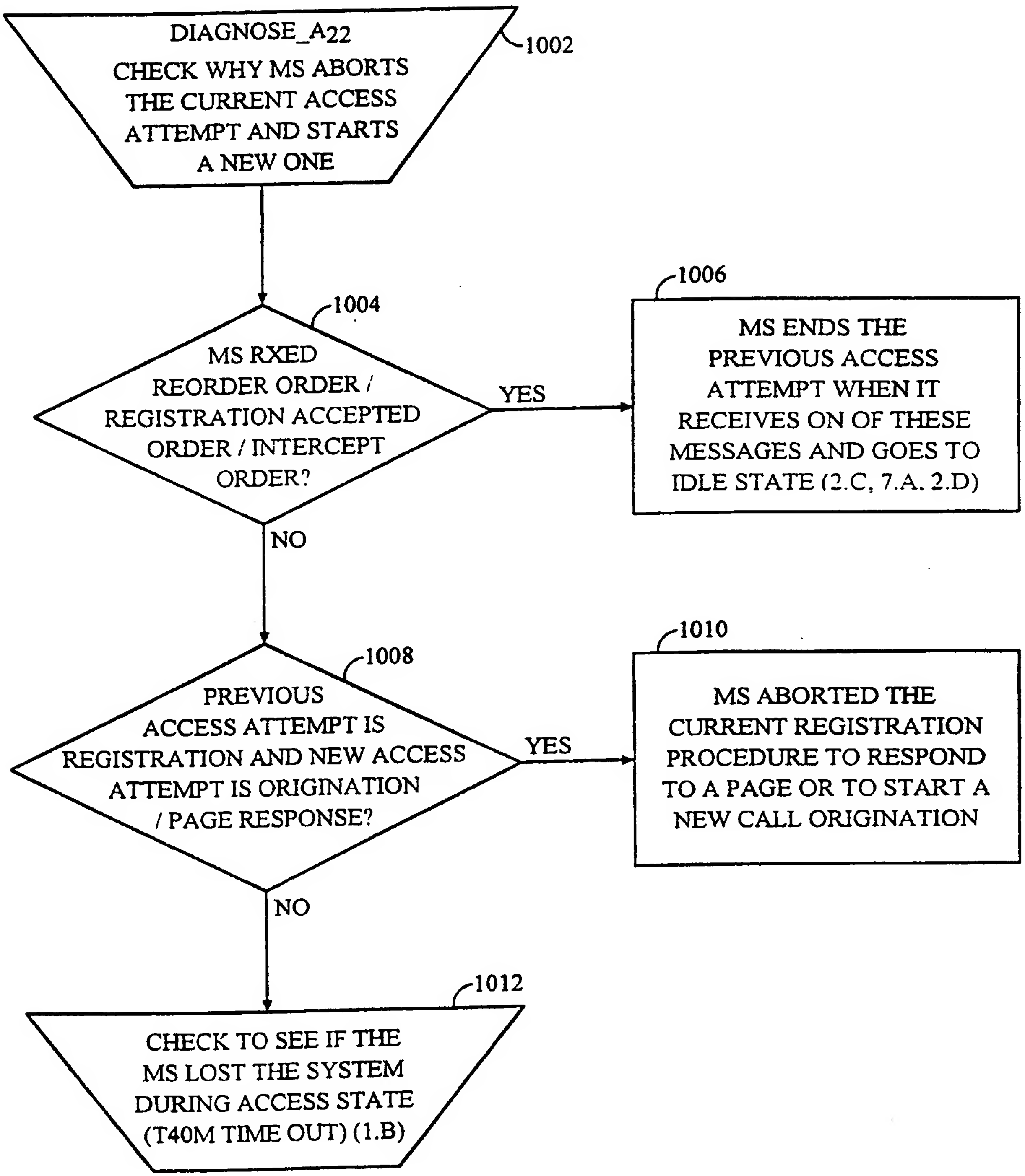
DIAGNOSE_A22
CHECK WHY MS ABORTS THE CURRENT ACCESS ATTEMPT AND STARTS A NEW ONE
1002
MS RXED REORDER ORDER / REGISTRATION ACCEPTED ORDER / INTERCEPT ORDER?
1004
YES
MS ENDS THE PREVIOUS ACCESS ATTEMPT WHEN IT RECEIVES ON OF THESE MESSAGES AND GOES TO IDLE STATE (2.C, 7.A. 2.D)
1006
NO
PREVIOUS ACCESS ATTEMPT IS REGISTRATION AND NEW ACCESS ATTEMPT IS ORIGINATION / PAGE RESPONSE?
1008
YES
MS ABORTED THE CURRENT REGISTRATION PROCEDURE TO RESPOND TO A PAGE OR TO START A NEW CALL ORIGINATION
1010
NO
CHECK TO SEE IF THE MS LOST THE SYSTEM DURING ACCESS STATE (T40M TIME OUT) (1.B)
1012

FIG. 10

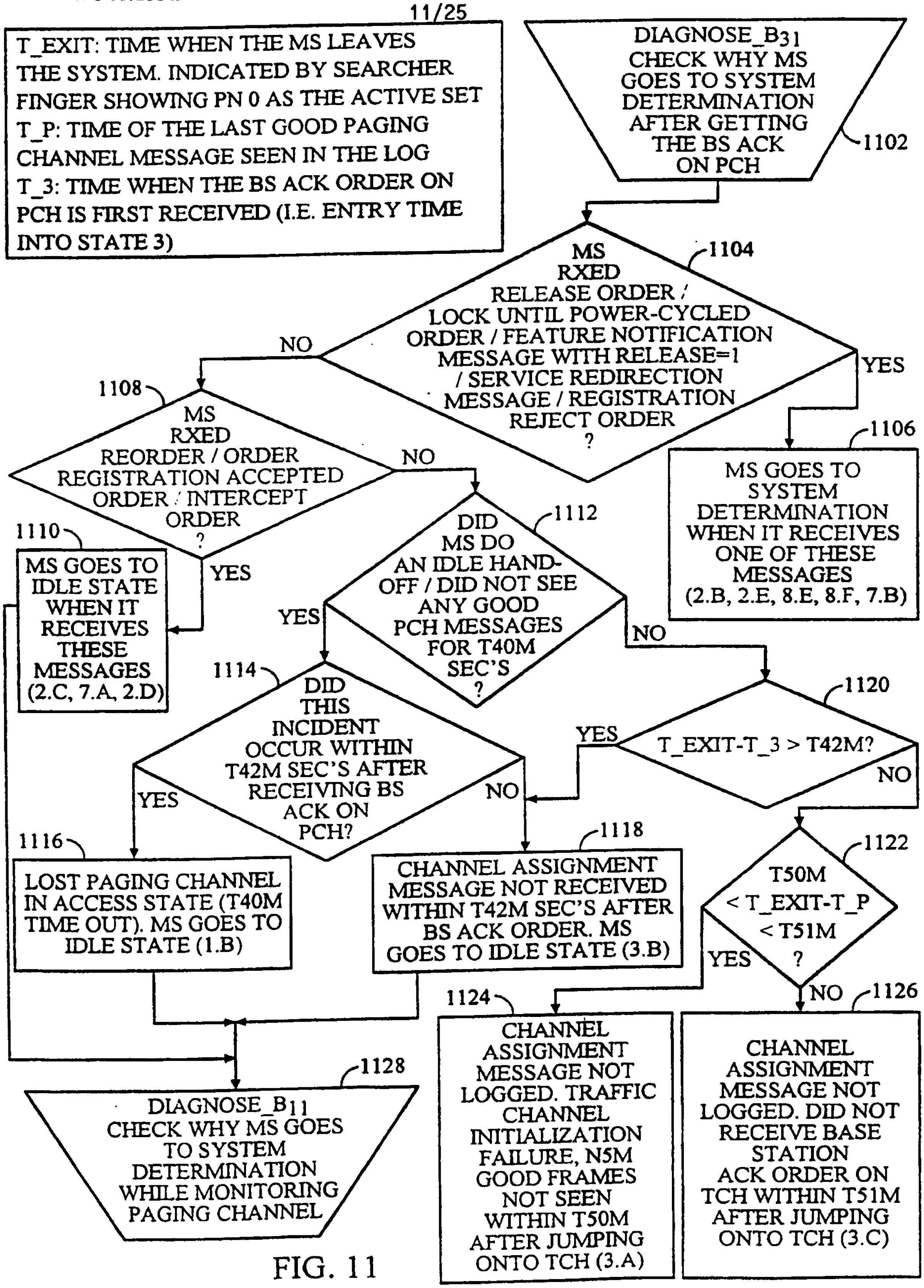
T_EXIT: TIME WHEN THE MS LEAVES THE SYSTEM. INDICATED BY SEARCHER FINGER SHOWING PN 0 AS THE ACTIVE SET
T_P: TIME OF THE LAST GOOD PAGING CHANNEL MESSAGE SEEN IN THE LOG
T_3: TIME WHEN THE BS ACK ORDER ON PCH IS FIRST RECEIVED (I.E. ENTRY TIME INTO STATE 3)
DIAGNOSE_B31 CHECK WHY MS GOES TO SYSTEM DETERMINATION AFTER GETTING THE BS ACK ON PCH
1102
MS RXED RELEASE ORDER / LOCK UNTIL POWER-CYCLED ORDER / FEATURE NOTIFICATION MESSAGE WITH RELEASE=1 / SERVICE REDIRECTION MESSAGE / REGISTRATION REJECT ORDER ?
1104
YES
NO
1106
MS GOES TO SYSTEM DETERMINATION WHEN IT RECEIVES ONE OF THESE MESSAGES (2.B, 2.E, 8.E, 8.F, 7.B)
1108
MS RXED REORDER / ORDER REGISTRATION ACCEPTED ORDER / INTERCEPT ORDER ?
NO
YES
1110
MS GOES TO IDLE STATE WHEN IT RECEIVES THESE MESSAGES (2.C, 7.A, 2.D)
1112
DID MS DO AN IDLE HAND-OFF / DID NOT SEE ANY GOOD PCH MESSAGES FOR T40M SEC'S ?
YES
NO
1114
DID THIS INCIDENT OCCUR WITHIN T42M SEC'S AFTER RECEIVING BS ACK ON PCH?
YES
NO
1120
T_EXIT-T_3 > T42M?
YES
NO
1116
LOST PAGING CHANNEL IN ACCESS STATE (T40M TIME OUT). MS GOES TO IDLE STATE (1.B)
1118
CHANNEL ASSIGNMENT MESSAGE NOT RECEIVED WITHIN T42M SEC'S AFTER BS ACK ORDER. MS GOES TO IDLE STATE (3.B)
1122
T50M < T_EXIT-T_P < T51M ?
YES
NO
1124
CHANNEL ASSIGNMENT MESSAGE NOT LOGGED. TRAFFIC CHANNEL INITIALIZATION FAILURE, N5M GOOD FRAMES NOT SEEN WITHIN T50M AFTER JUMPING ONTO TCH (3.A)
1126
CHANNEL ASSIGNMENT MESSAGE NOT LOGGED. DID NOT RECEIVE BASE STATION ACK ORDER ON TCH WITHIN T51M AFTER JUMPING ONTO TCH (3.C)
1128
DIAGNOSE_B11 CHECK WHY MS GOES TO SYSTEM DETERMINATION WHILE MONITORING PAGING CHANNEL

FIG. 11

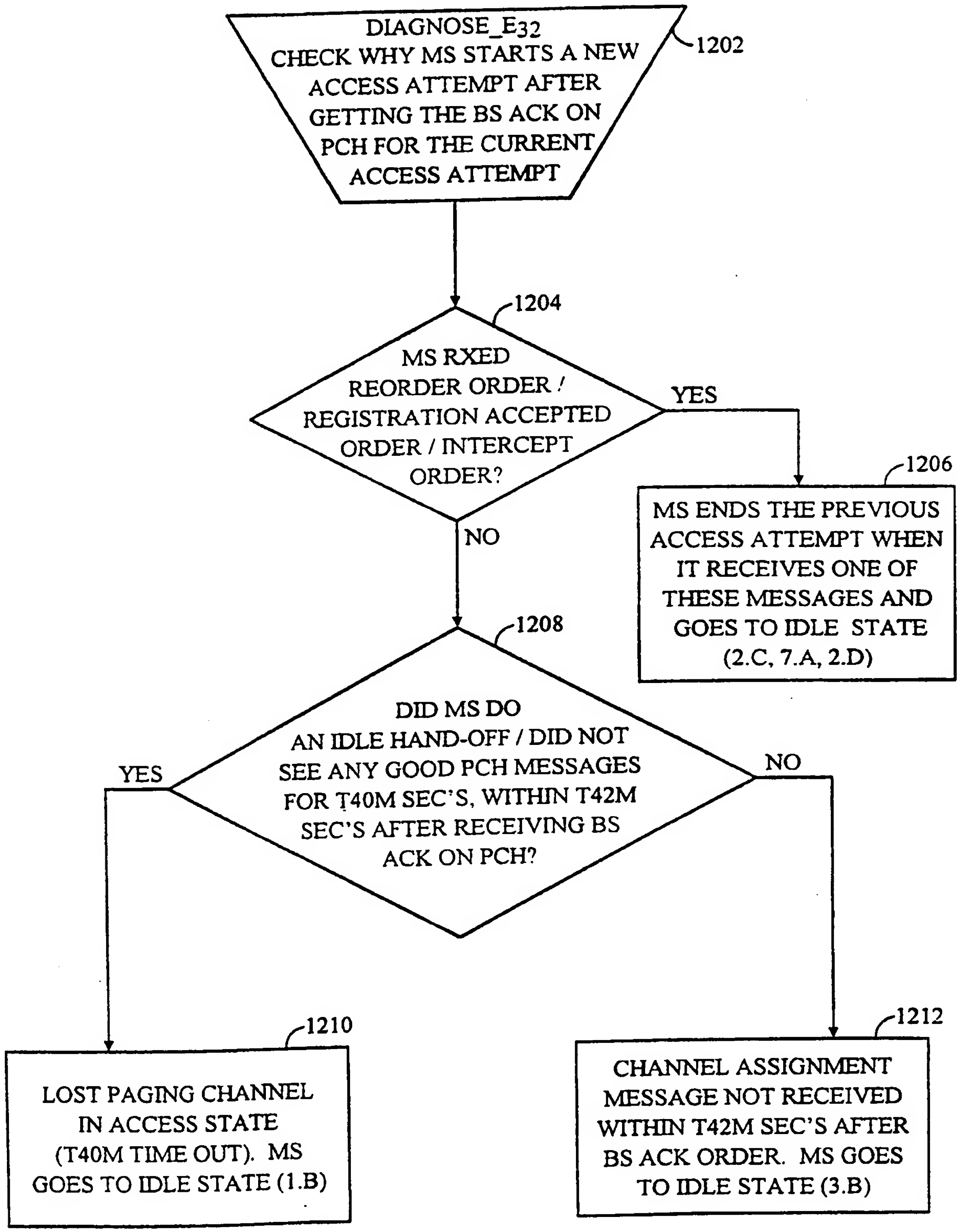
DIAGNOSE_E32
CHECK WHY MS STARTS A NEW ACCESS ATTEMPT AFTER GETTING THE BS ACK ON PCH FOR THE CURRENT ACCESS ATTEMPT
1202
1204
MS RXED REORDER ORDER / REGISTRATION ACCEPTED ORDER / INTERCEPT ORDER?
YES
1206
MS ENDS THE PREVIOUS ACCESS ATTEMPT WHEN IT RECEIVES ONE OF THESE MESSAGES AND GOES TO IDLE STATE (2.C, 7.A, 2.D)
NO
1208
DID MS DO AN IDLE HAND-OFF / DID NOT SEE ANY GOOD PCH MESSAGES FOR T40M SEC'S, WITHIN T42M SEC'S AFTER RECEIVING BS ACK ON PCH?
YES
NO
1210
LOST PAGING CHANNEL IN ACCESS STATE (T40M TIME OUT). MS GOES TO IDLE STATE (1.B)
1212
CHANNEL ASSIGNMENT MESSAGE NOT RECEIVED WITHIN T42M SEC'S AFTER BS ACK ORDER. MS GOES TO IDLE STATE (3.B)

FIG. 12

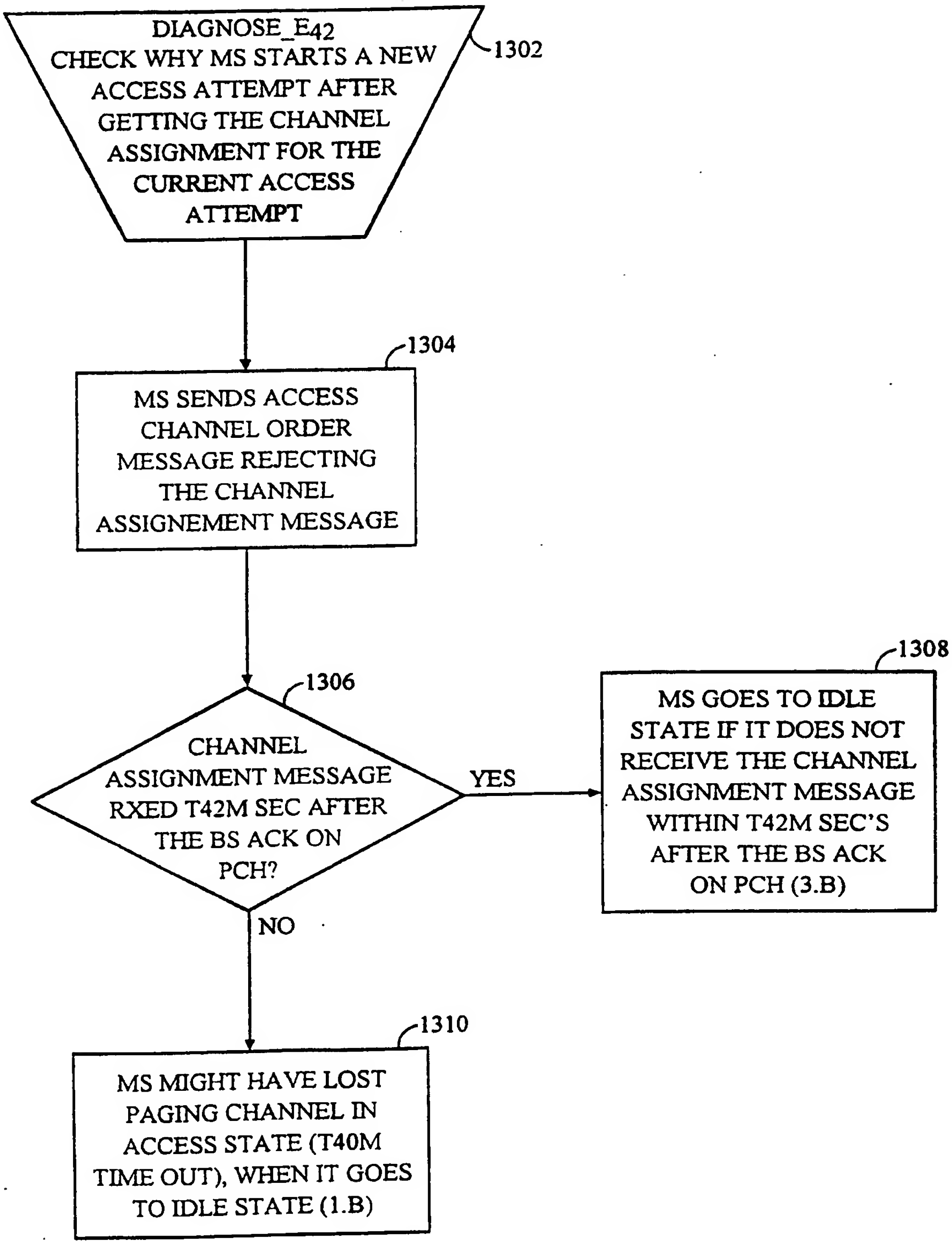
DIAGNOSE_E42
CHECK WHY MS STARTS A NEW ACCESS ATTEMPT AFTER GETTING THE CHANNEL ASSIGNMENT FOR THE CURRENT ACCESS ATTEMPT
1302
MS SENDS ACCESS CHANNEL ORDER MESSAGE REJECTING THE CHANNEL ASSIGNEMENT MESSAGE
1304
CHANNEL ASSIGNMENT MESSAGE RXED T42M SEC AFTER THE BS ACK ON PCH?
1306
YES
MS GOES TO IDLE STATE IF IT DOES NOT RECEIVE THE CHANNEL ASSIGNMENT MESSAGE WITHIN T42M SEC'S AFTER THE BS ACK ON PCH (3.B)
1308
NO
MS MIGHT HAVE LOST PAGING CHANNEL IN ACCESS STATE (T40M TIME OUT), WHEN IT GOES TO IDLE STATE (1.B)
1310

FIG. 13

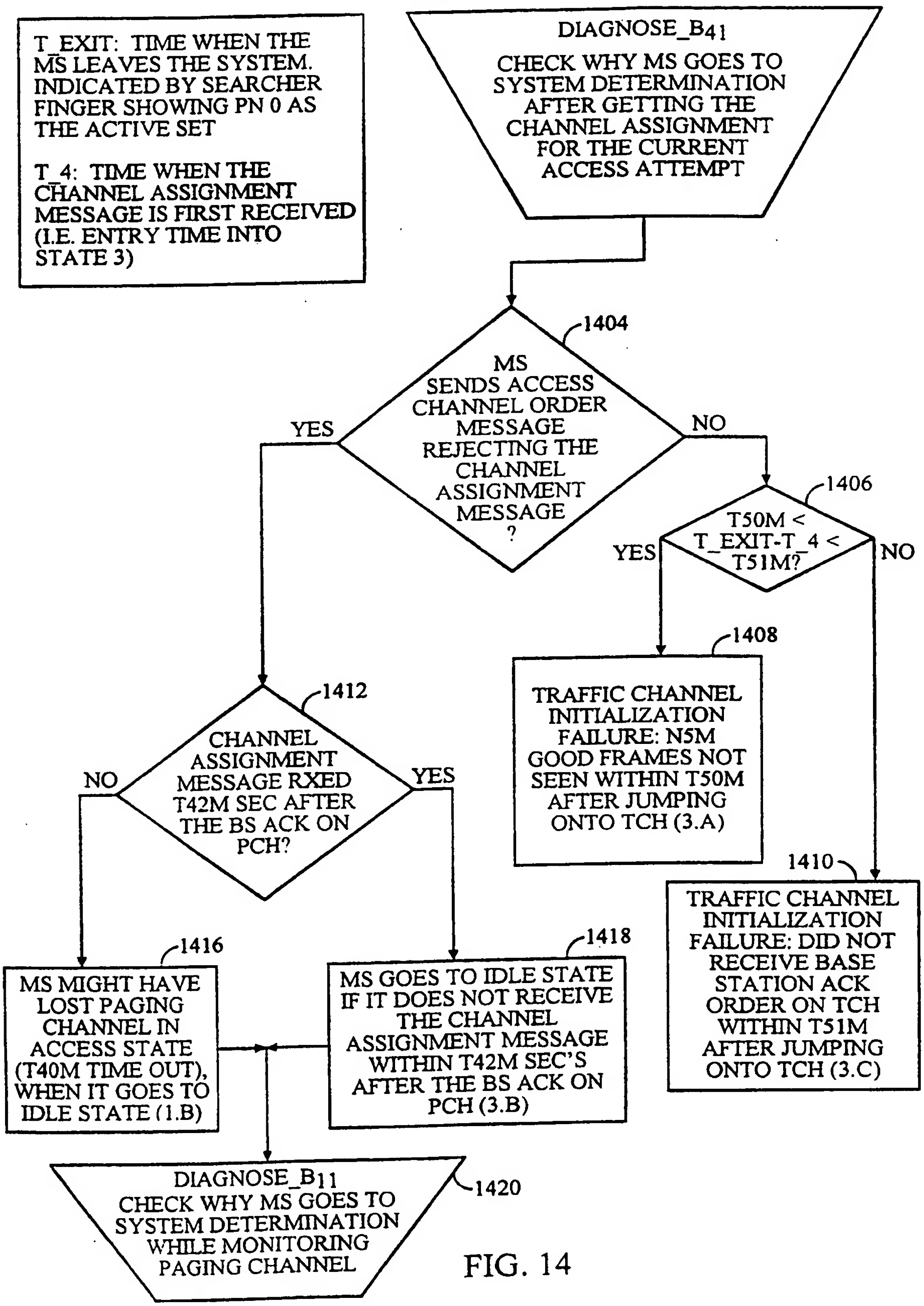
T_EXIT: TIME WHEN THE MS LEAVES THE SYSTEM. INDICATED BY SEARCHER FINGER SHOWING PN 0 AS THE ACTIVE SET
T_4: TIME WHEN THE CHANNEL ASSIGNMENT MESSAGE IS FIRST RECEIVED (I.E. ENTRY TIME INTO STATE 3)
DIAGNOSE_B41
CHECK WHY MS GOES TO SYSTEM DETERMINATION AFTER GETTING THE CHANNEL ASSIGNMENT FOR THE CURRENT ACCESS ATTEMPT
1404
MS SENDS ACCESS CHANNEL ORDER MESSAGE REJECTING THE CHANNEL ASSIGNMENT MESSAGE ?
YES
NO
1406
T50M < T_EXIT-T_4 < T51M?
YES
NO
1408
TRAFFIC CHANNEL INITIALIZATION FAILURE: N5M GOOD FRAMES NOT SEEN WITHIN T50M AFTER JUMPING ONTO TCH (3.A)
1410
TRAFFIC CHANNEL INITIALIZATION FAILURE: DID NOT RECEIVE BASE STATION ACK ORDER ON TCH WITHIN T51M AFTER JUMPING ONTO TCH (3.C)
1412
CHANNEL ASSIGNMENT MESSAGE RXED T42M SEC AFTER THE BS ACK ON PCH?
NO
YES
1416
MS MIGHT HAVE LOST PAGING CHANNEL IN ACCESS STATE (T40M TIME OUT), WHEN IT GOES TO IDLE STATE (1.B)
1418
MS GOES TO IDLE STATE IF IT DOES NOT RECEIVE THE CHANNEL ASSIGNMENT MESSAGE WITHIN T42M SEC'S AFTER THE BS ACK ON PCH (3.B)
DIAGNOSE_B11
CHECK WHY MS GOES TO SYSTEM DETERMINATION WHILE MONITORING PAGING CHANNEL
1420

FIG. 14

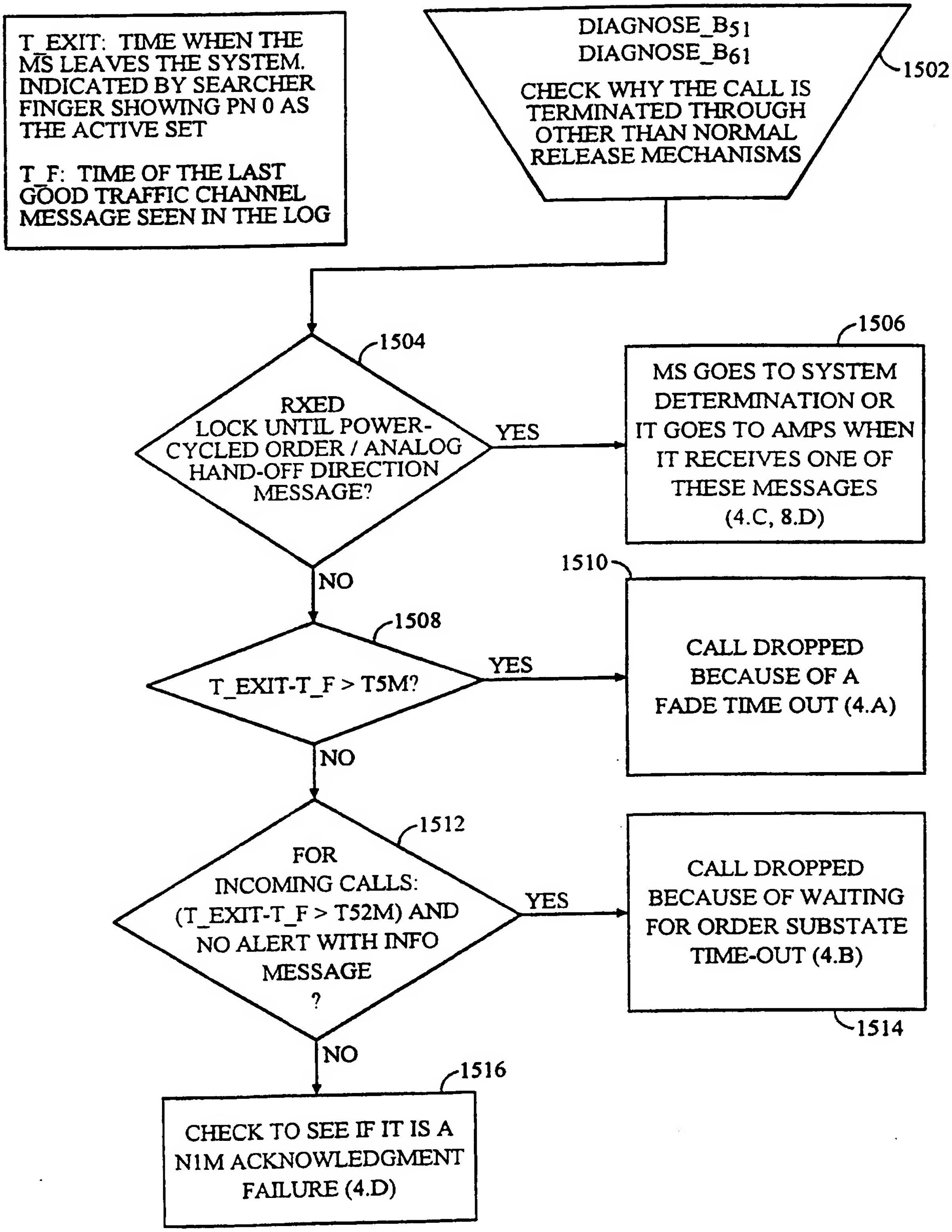
T_EXIT: TIME WHEN THE MS LEAVES THE SYSTEM. INDICATED BY SEARCHER FINGER SHOWING PN 0 AS THE ACTIVE SET
T_F: TIME OF THE LAST GOOD TRAFFIC CHANNEL MESSAGE SEEN IN THE LOG
DIAGNOSE_B51
DIAGNOSE_B61
CHECK WHY THE CALL IS TERMINATED THROUGH OTHER THAN NORMAL RELEASE MECHANISMS
1502
1504
RXED LOCK UNTIL POWER-CYCLED ORDER / ANALOG HAND-OFF DIRECTION MESSAGE?
YES
1506
MS GOES TO SYSTEM DETERMINATION OR IT GOES TO AMPS WHEN IT RECEIVES ONE OF THESE MESSAGES (4.C, 8.D)
NO
1508
T_EXIT-T_F > T5M?
YES
1510
CALL DROPPED BECAUSE OF A FADE TIME OUT (4.A)
NO
1512
FOR INCOMING CALLS: (T_EXIT-T_F > T52M) AND NO ALERT WITH INFO MESSAGE ?
YES
CALL DROPPED BECAUSE OF WAITING FOR ORDER SUBSTATE TIME-OUT (4.B)
1514
NO
1516
CHECK TO SEE IF IT IS A N1M ACKNOWLEDGMENT FAILURE (4.D)

FIG. 15

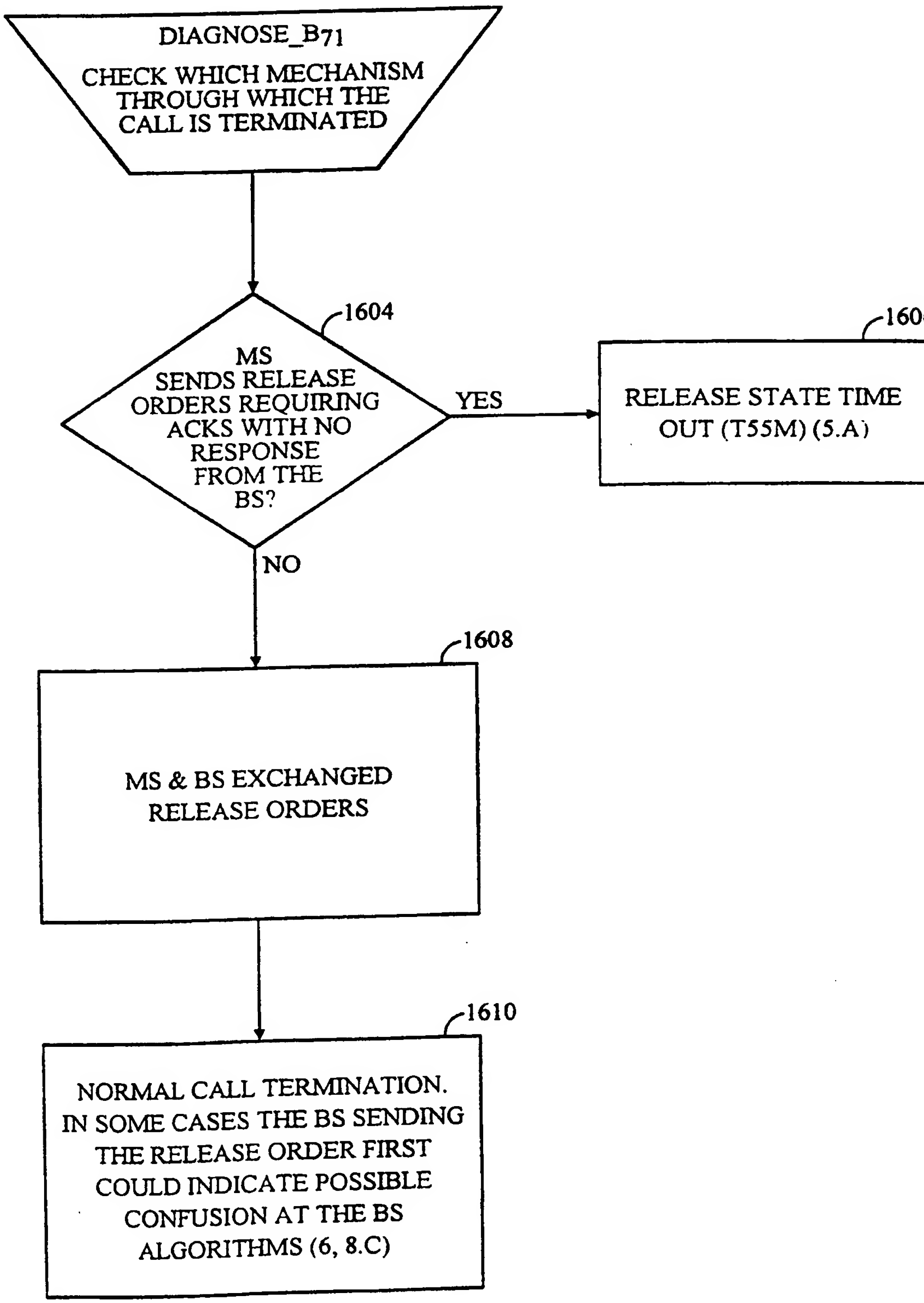
DIAGNOSE_B71
CHECK WHICH MECHANISM THROUGH WHICH THE CALL IS TERMINATED
1604
MS SENDS RELEASE ORDERS REQUIRING ACKS WITH NO RESPONSE FROM THE BS?
YES
NO
1606
RELEASE STATE TIME OUT (T55M) (5.A)
1608
MS & BS EXCHANGED RELEASE ORDERS
1610
NORMAL CALL TERMINATION. IN SOME CASES THE BS SENDING THE RELEASE ORDER FIRST COULD INDICATE POSSIBLE CONFUSION AT THE BS ALGORITHMS (6, 8.C)

FIG. 16

------------------- SAMPLE OUTPUT OF ANALYZE -------------------

ANALYZE VERSION 3.6, WED APR 16 10:00:40 1997

PHONE : QCP-800, CDMA CELLULAR
FILES : M1517068.906, M1517068.906
SOFTWARE VERSION G0223K02, REV 223
MIN1 (555) 123-9999, MIN2 (555)123-8906, ESN 0X000123A8

PARETO ANALYSIS

FILE NAME		ALL FILES	FIL 1	FIL 2
TOTAL NUMBER OF CASES				
1710 — 1. PAGING CHANNEL DROPPED:	162	100.00%	81	81
1711 — A. LOSS OF PAGING CHANNEL IN IDLE STATE (T30M=3S)	44	27.16%	22	22
1712 — B. LOSS OF PAGING CHANNEL IN ACCESS STATE (T40M=1S)	6	3.70%	3	3
1713 — C. PAGING CHANNEL DROPPED (NSE OR SLEEP)	12	7.41%	6	6
1720 — 2. ACCESS ATTEMPT FAILURE OR ABORTED:				
1721 — A. MS POSSIBLY EXHAUSTED ALL ACCESS PROBES	0	0.00%	0	0
1722 — B. RECEIVED RELEASE ORDER	0	0.00%	0	0
1723 — C. RECEIVED REORDER ORDER	0	0.00%	0	0
1724 — D. RECEIVED INTERCEPT ORDER	0	0.00%	0	0
1725 — E. RECEIVED LOCK UNTIL POWER-CYCLED ORDER	0	0.00%	0	0
1726 — F. UNKNOWN? (USER PRESSED END)	0	0.00%	0	0
1730 — 3. TRAFFIC CHANNEL INITIALIZATION FAILURE:				
1731 — A. TCI VALID FRAME TIME OUT (T50M=200S)	6	3.70%	3	3
1732 — B. CHANNEL ASSIGNMENT MESSAGE NOT RECEIVED (T42M=12S)	0	0.00%	0	0
1733 — C. BS ACK ON TRAFFIC CHANNEL NOT RECEIVED (T51=2S)	2	1.23%	1	1
1734 — D. UNKNOWN?	0	0.00%	0	0

FIG. 17A

1740 — 4. DROPPED CALL:					
1741 — A. FADE TIME OUT (T5M=5S)	2	1.23%	1	1	
1742 — B. WFO TIME OUT (T52M=5S)	0	0.00%	0	0	
1743 — C. RECEIVED LOCK UNTIL POWER-CYCLED ORDER	0	0.00%	0	0	
1744 — D. UNKNOWN? (POSSIBLE N1M ACK FAILURE)	2	1.23%	1	1	
1750 — 5. BS RELEASE ORDER NOT RECEIVED:					
1751 — A. POSSIBLE RELEASE STATE TIME OUT (T55M=2S)	8	4.94%	4	4	
1760 — 6. NORMAL CALL TERMINATION	74	45.68%	37		37
1770 — 7. REGISTRATION PROCEDURES:					
1771 — A. REGISTRATION SUCCESSFUL	0	0.00%	0	0	
1772 — B. REGISTRATION REJECTED	0	0.00%	0	0	
1773 — C. REGISTRATION ATTEMPT ACKNOWLEDGED	0	0.00%	0	0	
1780 — 8. MISCELLANEOUS:					
1781 — A. SPURIOUS BS ACK ON PAGING CHANNEL	0	0.00%	0	0	
1782 — B. SPURIOUS CHANNEL ASSIGNMENT MESSAGE	0	0.00%	0	0	
1783 — C. MS RELEASE ORDER NOT SENT	0	0.00%	0	0	
1784 — D. ANALOG HANDOFF DONE	0	0.00%	0	0	
1785 — E. RECEIVED FEATURE NOTIF MSG WITH RELEASE=1	0	0.00%	0	0	
1786 — F. RECEIVED SERVICE REDIRECTION MSG	0	0.00%	0	0	
1787 — G. PHONE REDIRECTED TO ANALOG IN PAGING CHANNEL	0	0.00%	0	0	
1788 — H. PHONE IGNORED CHANNEL ASSIGNMENT MESSAGE	0	0.00%	0	0	

FIG. 17B

1800 — TIME STAMP 1802	PILOT PN AND PILOT ECIO INFORMATION 1804	MESSAGE FLOW DIRECTION 1806	CHANNEL {ACK_SEQ, MSG_SEQ, ACK_REQ, VALID_ACK 1808	MESSAGE 1809
1810 — SYNC CHANNEL MESSAGES	1814	1815		1817
1812 — [HH:MM:SS.000 1813	[PN, EC/IO] SEARCHER INFO	B : : : > M	SYNC CH 1816	SYNC MESSAGE]
1820 — PAGING CHANNEL MESSAGES				
HH:MM:SS.000	[PN, EC/IO] SEARCHER INFO	B - - - > M	PCH {M,M,M,Y}	BASE STATION ACKNOWLEDGEMENT ORDER
HH:MM:SS.000	[PN, EC/IO] SEARCHER INFO	B - - - > M	PCH {M,M,M,N}	CHANNEL ASSIGNMENT MESSAGE
1830 — ACCESS CHANNEL MESSAGES				
HH:MM:SS.000	[PN, EC/IO] SEARCHER INFO	B <<<< M	ACSS CH	ACCESS PROBE (PROBE_NO, SEQ_NO)
HH:MM:SS.000	[PN, EC/IO] SEARCHER INFO	B < - - - M	ACH {M,M,M,N}	ORIGINATION OR PAGE RESPONSE OR REGISTRATION MESSAGE
1840 — TRAFFIC CHANNEL MESSAGES	1844			
HH:MM:SS.000	[PN1, PN2, PN3] FINGER INFO	B = = = > M	FTC {M,M,M}	BASE STATION ACK ORDER
HH:MM:SS.000	[PN1, PN2, PN3] FINGER INFO	B = = = > M	FTC {M,M,M}	RELEASE ORDER
HH:MM:SS.000	[PN1, PN2, PN3]	B <= = = M	RTC {M,M,M}	RELEASE ORDER

FIG. 18

	CASE 1:				
1910	NOTE* : LOST PAGING CHANNEL IN IDLE STATE (T30M=3S) AROUND 00:00:07.375				
	CASE 2:				
1920	00:00:10.935	[176, -6.5]	B : : : > M	SYNC CH	SYNC MESSAGE
1921	19:21:28.745	[176, -6.6]	B <--- M	ACH {0,0,1,Y}	PAGE RESPONSE MESSAGE
1922	19:21:30.717	[176, ,176]	B ===> M	FTC {7,0,1}	BASE STATION ACK ORDER
1923	19:21:48.318	[176, 168, 172]	B ===> M	FTC {5,5,0}	RELEASE ORDER
1924	19:21:48.356	[176, 168, 172]	B <=== M	RTC {7,6,0}	RELEASE ORDER
1925	19:21:48.358	[176, 168, 172]	B ===> M	FTC {5,5,0}	RELEASE ORDER
1926	19:21:48.397	[176, 168, 172]	B ===> M	FTC {5,5,0}	RELEASE ORDER
1927	NOTE: NORMAL CALL TERMINATION				
	CASE 3:				
1930	19:21:48.867	[176, -6.5]	B : : : > M	SYNC CH	SYNC MESSAGE
1931	19:22:02.026	[176, -6.5]	B <--- M	ACH {0,1,1,Y}	PAGE RESPONE MESSAGE
1932	19:22:02.303		B <<<< M	ACSS CH	ACCESS PROBE
1933	19:22:02.566	[176, -6.5]	B ---> M	PCH {1,1,0,Y}	BASE STATION ACK
1934	19:22:03.526	[176, -7.3]	B ---> M	PCH {1,2,0,N}	CHANNEL ASSIGNMENT MSG
1935	19:22:04.078	[176, ,]	B ===> M	FTC {7,0,1}	BASE STATION ACK ORDER
1936	19:22:29.058	[176, ,168]	B ===> M	FTC {7,7,0}	RELEASE ORDER
1937	19:22:29.076	[176, ,168]	B <=== M	RTC {0,7,0}	RELEASE ORDER
1938	19:22:29.097	[176, ,168]	B ===> M	FTC {7,7,0}	RELEASE ORDER
1939	19:22:29.138	[176, ,168]	B ===> M	FTC {7,7,0}	RELEASE ORDER
1940	NOTE: NORMAL CALL TERMINATION				
	CASE 4:				
1950	19:22:29.637	[176, -5.0]	B : : : > M	SYNC CH	SYNC MESSAGE
1951	NOTE* : LOST PAGING CHANNEL IN IDLE STATE (T30M=3MS) AROUND 19:22:29.377				

CASE STUDY OF M0222430.161

	CASE 1:				
1960	19:22:29.637	[176, -5.0]	B : : : > M	SYNC CH	SYNC MESSAGE
1961	NOTE* : LOST PAGING CHANNEL IN IDLE STATE (T30M=3MS) AROUND 19:22:29.377				
	CASE 2:				
1970	21:22:49.145	[225, -15.0]	B <--- M	ACH (7,4,1,N)	ORIGINATION MESSAGE
1971	NOTE* : DECLARED LOSS OF PAGING CHANNEL IN ACCESS STATE (T40M=1S) AFTER 21:22:49.427				
1972	**WARNING** : THIS IS THE LAST CASE OF THIS FILE AND COULD BE A FALSE ALARM !				

FIG. 19

2000 — NEIGHBOR LIST PROBLEMS

THE FOLLOWING PAIRS OF PILOTS MAY HAVE NEIGHBOR LIST PROBLEMS:

2002 — PILOTS PN 192 AND PN 30 ARE NOT NEIGHBORS

2004 — PILOT PN 174 IS NOT IN NEIGHBOR LIST OF PN 354 : NON SYMMETRIC NEIGHBORS
PILOT PN 414 IS NOT IN NEIGHBOR LIST OF PN 354 : NON SYMMETRIC NEIGHBORS

THESE PILOTS CAUSED PROBLEMS IN FILE M1517068.906

2006 — (402, 480) (402, 36) (66, 36) (258, 288) (18, 120) (360, 348) (396, 192)
(396, 6) (6, 192) (210,192) (186, 264)

THESE PILOTS PAIRS (A, B) FORM NON-SYMMETRIC NEIGHBORS, WHERE PN A IS NOT IN NEIGHBOR LIST OF PN B AND COULD CAUSE PROBLEMS IN FILE M1517068.906

GENERAL OBSERVATIONS

2010 — * HISTOGRAM OF REVERSE TRAFFIC CHANNEL MESSAGE RETRANSMISSIONS:

A : NO OF TIMES A RTC MESSAGE IS RETRANSMITTED BEFORE GETTING ACKNOWLEDGMENT
B : FREQUENCY OF OCCURRENCE OF EACH RETRANSMISSION COUNT

A:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	FILE
B:	156	22	11	2	4	1	0	0	0	0	0	0	0	0	M1517068.906
B:	156	22	11	2	4	1	0	0	0	0	0	0	0	0	M1517068.906
B:	312	44	22	4	8	2	0	0	0	0	0	0	0	0	TOTAL

FIG. 20A

2012 — * HAND-OFF DISTRIBUTION :
PERCENTAGE OF TRAFFIC-CHANNEL TIME THE MOBILE STATION IS IN A GIVEN HAND-OFF

HANDOFF :	1-WAY	2W-SF	2W-SR	3W-SF	3W-SF-SR	3W-SR	HARD	OTHER (4W, 5W & 6W)	
PERCENT :	74.62	17.14	1.71	1.13	5.39	0.00	0.00	0.00	M1517068.906
PERCENT :	74.62	17.14	1.71	1.13	5.39	0.00	0.00	0.00	M1517068.906
PERCENT :	74.62	17.14	1.71	1.13	5.39	0.00	0.00	0.00	COMBINED

2014 — * HAND-OFF SET-UP TIME STATISTICS :
HAND-OFF SET-UP TIME = (EXTENDED) HANDOFF DIR MSG TIME - PILOT STRENGTH MEASUREMENT MSG TIME

MEAN(SEC)	STD(SEC)	MIN(SEC)	MAX(SEC)	SIZE(SAMPLES)	FILE
0.383	0.169	0.160	0.840	30	M1517068.906
0.383	0.169	0.160	0.840	30	M1517068.906
0.383	0.169	0.160	0.840	60	COMBINED

2016 — * CALL SET-UP TIME STATISTICS :
CALL SET-UP TIME = FIRST TRAFFIC CH BASE STATION ACK TIME - LAST ACCESS PROBE TIME

MEAN(SEC)	STD(SEC)	MIN(SEC)	MAX(SEC)	SIZE(SAMPLES)	FILE
1.094	0.080	0.957	1.254	36	M1517068.906
1.094	0.080	0.957	1.254	36	M1517068.906
1.094	0.080	0.957	1.254	72	COMBINED

FIG. 20B

2018 —* ACQUISITION TIME STATISTICS :

ACQUISITION TIME = TIME WHEN SEARCHER SHOWS ASSET PN 0 - SYNC MESSAGE TIME

MEAN (SEC)	STD (SEC)	MIN (SEC)	MAX (SEC)	SIZE (SAMPLES)	FILE
3.269	5.818	0.117	19.543	78	M1517068.906
3.269	5.818	0.117	19.543	78	M1517068.906
3.269	5.818	0.117	19.543	156	COMBINED

2020 —* MULTIPATH STATISTICS :

NUMBER OF MULTIPATHS TRACKED BY FINGERS, WHEN THERE IS ONLY ONE PILOT IN THE ACTIVE SET

MEAN	STD	MIN	MAX	SIZE (SAMPLES)	FILE
1.032	0.178	1.000	3.000	4902	M1517068.906
1.032	0.178	1.000	3.000	4902	M1517068.906
1.032	0.178	1.000	3.000	9804	COMBINED

2022 —* IN 30 OUT OF 44 PAGING CHANNEL DROPS (T30M=3SEC), NO GOOD PAGING CHANNEL MESSAGE WAS RECEIVED DUE TO FAILURE TO JUMP PROPERLY TO HYPERSPACE.

2024 —* THE FOLLOWING PILOTS HAVE BEEN VISITED BY THE PHONE

IN FILE M1517068.906

342 354 420 372 258 246 306 18

IN FILE M1517068.906

342 354 420 372 258 246 306 18

FIG. 20C

2026 * HISTOGRAM OF MAXIMUM NO. OF ACCESS PROBES/CALL :
[A, B] WHERE A = NO. OF PROBES/CALL, B = FREQUENCY OF OCCURRENCE OF A PROBES/CALL

IN FILE M1517068.906	[1, 41]	[2, 6]	[3, 3]	[6, 1]	[8, 1]	[13, 1]
IN FILE M1517068.906	[1, 41]	[2, 6]	[3, 3]	[6, 1]	[8, 1]	[13, 1]

2028 * THERE ARE_CASES OF HARD HAND OFF SEEN IN THE INPUT FILES.

2030 * THERE ARE_CASES OF ANALOG HAND OFF SEEN IN THE INPUT FILES.

2032 * BASE STATION INCLUDED ACTIVE PN'S IN NEIGHBOR LIST UPDT MSG : STANDARD VIOLATION
(REF : IS-95, 7.6.6.2.1.2)

IN FILE M1517068.906 AT :
08:08:28.103, 08:08:44.061, 08:08:46.700, 08:09:01.316, 08:09:36.712, 08:09:38.592,
08:09:43.232, 08:09:55.207, 08:10:38.405, 08:10:46.878, 08:11:06.930, 08:11:22.745,
08:11:41.353, 08:12:00.782, 08:12:17.898, 08:12:42.462, 08:12:54.962, 08:13:05.701,

FIG. 20D

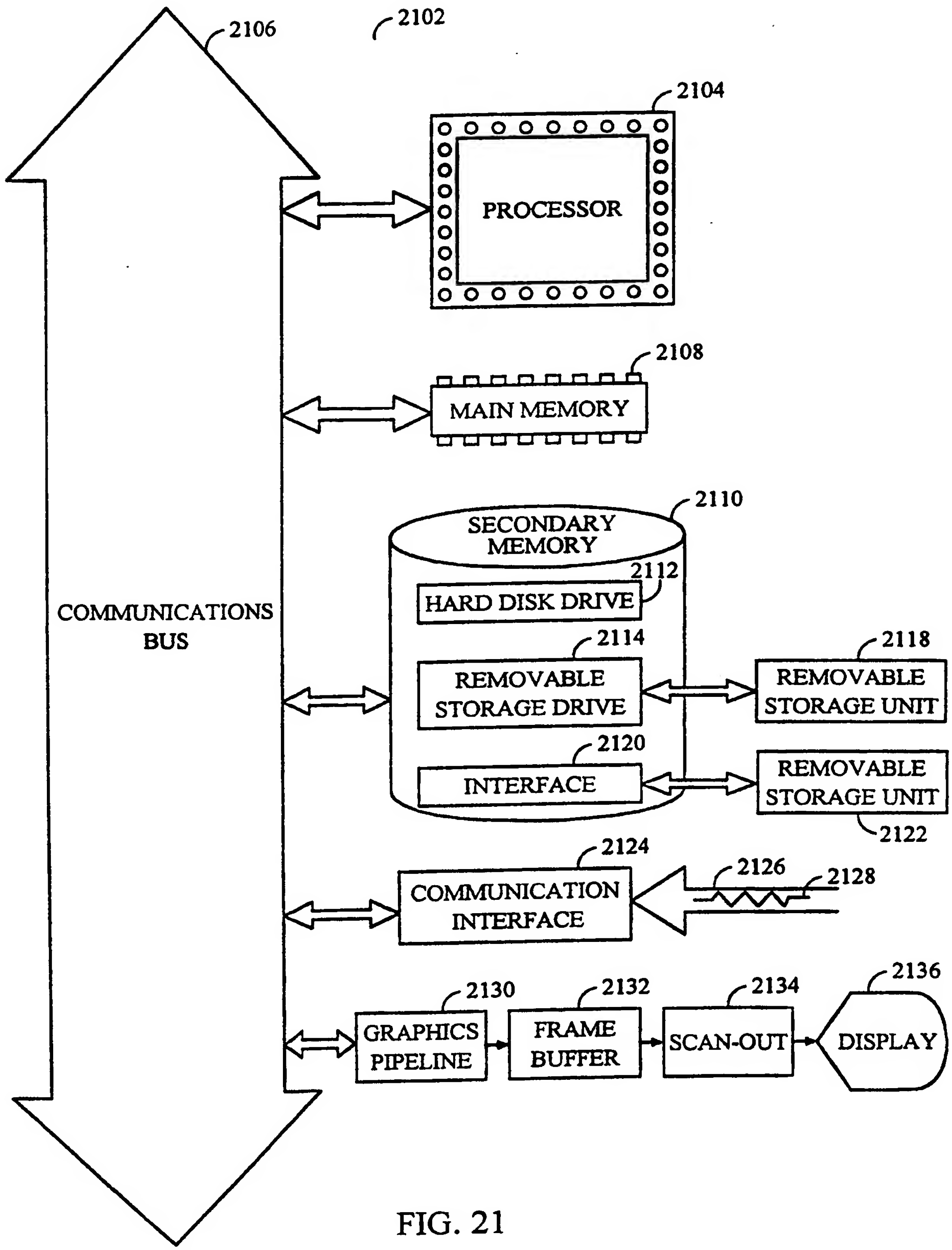
2102
2106
2104
PROCESSOR
2108
MAIN MEMORY
2110
SECONDARY MEMORY
2112
HARD DISK DRIVE
2114
REMOVABLE STORAGE DRIVE
2118
REMOVABLE STORAGE UNIT
2120
INTERFACE
REMOVABLE STORAGE UNIT
2122
COMMUNICATIONS BUS
2124
COMMUNICATION INTERFACE
2126
2128
2130
GRAPHICS PIPELINE
2132
FRAME BUFFER
2134
SCAN-OUT
2136
DISPLAY

FIG. 21

INTERNATIONAL SEARCH REPORT

Inte ›nal Application No
PCT/US 98/22767

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   H04Q7/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6   H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 93 15569 A (COMARCO INC) 5 August 1993 see page 8, line 4 - line 27; figures 1,7 see page 21, line 15 - line 23 see page 24, line 21 - page 26, line 21 see page 37, line 25 - page 38, line 26 ---	1,26,51, 54
A	GLOGER M ET AL: "TYPE-APPROVAL MEASUREMENTS ON DECT FIXED PARTS (FP) AND PORTABLE PARTS (PP) TO TBR22" NEWS FROM RHODE & SCHWARZ, vol. 35, no. 148, 1995, pages 9-11, XP000645891 see the whole document -----	1,26,51, 54

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 January 1999	10/02/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Dionisi, M

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte nal Application No
PCT/US 98/22767

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9315569 A	05-08-1993	NONE	